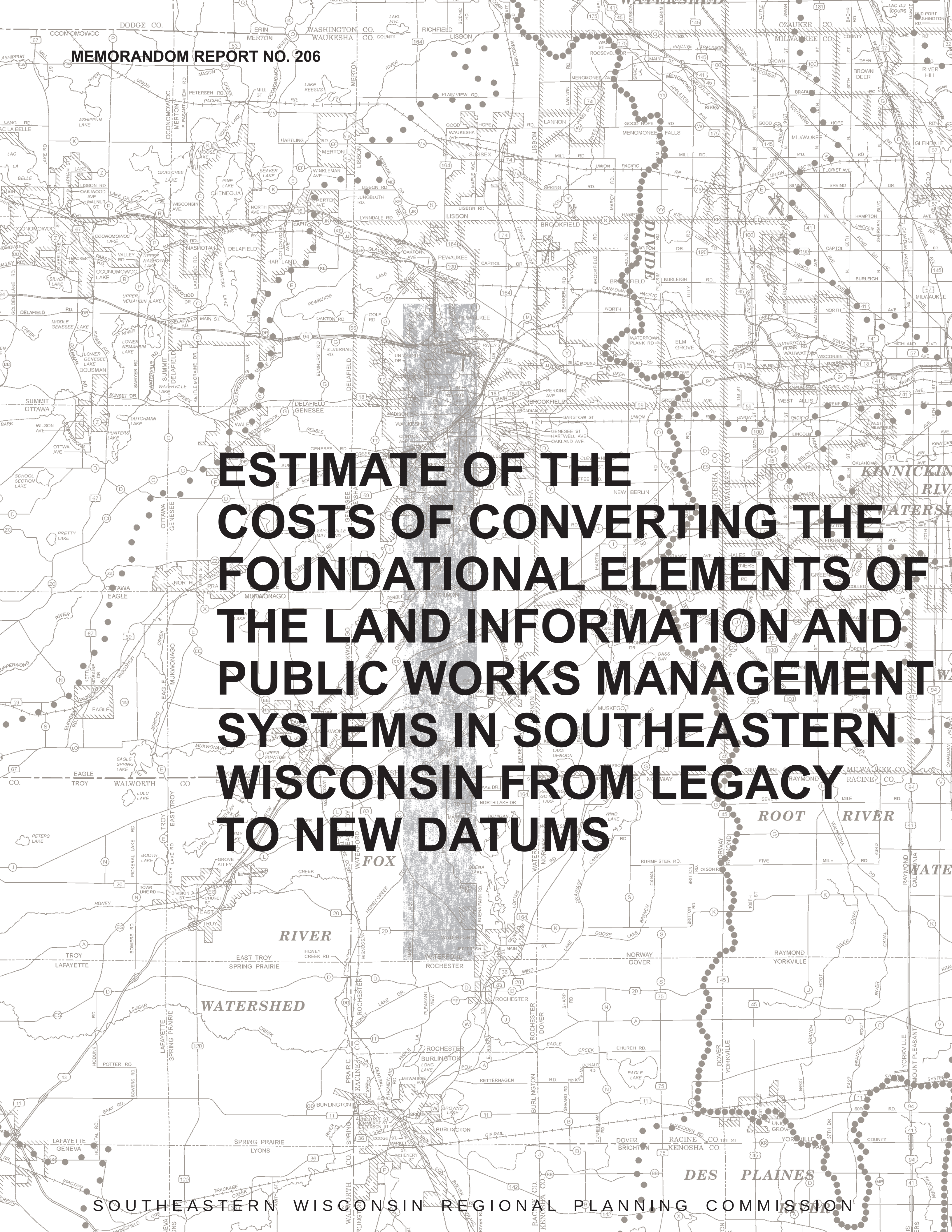

MEMORANDOM REPORT NO. 206

ESTIMATE OF THE COSTS OF CONVERTING THE FOUNDATIONAL ELEMENTS OF THE LAND INFORMATION AND PUBLIC WORKS MANAGEMENT SYSTEMS IN SOUTHEASTERN WISCONSIN FROM LEGACY TO NEW DATUMS

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MEMORANDUM REPORT
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ESTIMATE OF THE COSTS OF CONVERTING THE FOUNDATIONAL ELEMENTS OF THE LAND INFORMATION AND PUBLIC WORKS MANAGEMENT SYSTEMS IN SOUTHEASTERN WISCONSIN FROM LEGACY TO NEW DATUMS

INTRODUCTION AND BACKGROUND

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 System 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 11,985 U.S. Public Land Survey System corners and ancillary survey stations 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.

Legacy and New Datums

All of the horizontal control survey work within the Region has been referenced to the North American Datum of 1927 (NAD 27), a datum based upon the Clarke Spheroid of 1866, a spheroid which fits the North American Continent and the Southeastern Wisconsin Region well. 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), utilizing a new reference spheroid known as Geodetic Reference System of 1980 (GRS 80). 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). The new horizontal datum was subsequently adjusted to create NAD 83 (1991), with further adjustments proposed by the National Geodetic Survey (NGS). The use of these new datums within the Region does not provide any significant advantages over the continued use of the old datums. Since no significant benefits can be shown to accrue from the use of the new datums, and since a change in datums would incur very high costs, the Commission has determined to continue to utilize the older datums as a basis for its surveying and mapping activities within Southeastern Wisconsin. To facilitate the use of the new datums within the Region by such agencies as may determine to do so, the Commission in 1993 and 1994 developed computational systems that would permit the ready bidirectional transformation of coordinates and elevations between the horizontal and vertical datums concerned. These computational systems are described in SEWRPC Technical Report No. 34, *A Mathematical Relationship Between NAD 27 and NAD 83(91) State Plane Coordinates in Southeastern Wisconsin,* December 1994; and SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin,* December 1995.

Review and Reevaluation of Regional Control Survey Network

The aforereferenced changes in datums, the further adjustment of the "new" datums to create NAD 83 (2007) and NAVD 88 (2007), coupled with changes in surveying and mapping technology, however, caused the Commission to undertake in 2008 a review and evaluation of the regional control survey and mapping program and of the Commission role in that program. These changes included, in addition to the adjustments of the once "new" Federal 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; as well as to recommend that county and local governments in the Region similarly continue such utilization.

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).

Commission Bidirectional Transformation Methodology

On May 8, 2008, the Commission retained Earl F. Burkholder, PS, PE, consulting geodetic survey engineer, to develop the new bidirectional transformation methodology called for in SEWRPC Technical Report No. 45. The results of Mr. Burkholder's work, carried out with the assistance of a Commission Task Force, are set forth in SEWRPC Technical Report No. 49, *Bidirectional Transformation of Legacy and Current Survey Control Data Within Southeastern Wisconsin,* May 2010.

Testing of the new three-dimensional, bidirectional transformation methodology developed by Mr. Burkholder indicated that the transformations provided are clearly reliable for 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. The cited report indicated, however, that where higher-order survey accuracies are required, the conduct of field surveys referred to the NAD 27 and NGVD 29 datums were recommended. Importantly, the SEWRPC Technical Report No. 49 demonstrated that no conversion of these legacy datums to the newer NAD 83 (2007) and NAVD 88 (2007) was 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 could be readily used with the Commission recommended NAD 27 and NGVD 29 datums.

RESURVEY COSTS AND BENEFITS

The Commission determined to continue to utilize the legacy datums as a basis for its surveying and mapping activities, and to continue to recommend to its constituent counties and municipalities the continued use of those datums. That determination was based upon consideration of the costs and benefits of a conversion to the new datums of not only the extensive control survey network that has been established within the Region, but of other foundational elements of the parcel-based land information systems being created within the Region—the topographic and cadastral base maps—and of the vast amounts of data being accumulated in those information systems. For counties where substantial efforts have been made to develop high-order horizontal and vertical control survey networks, to prepare accurate topographic and cadastral maps, and to incorporate geospatial inventories of land use, soils, woodlands, wetlands, floodlands and environmental corridors, the Commission has, in the past, estimated the cost of datum conversion to approximate one to two million dollars per county. Proponents of conversion have yet to quantify and document the value of any substantial benefits that might offset these conversion costs.

The use of the new datums within the Region would provide no improvement over the continued use of the legacy datums for local area mapping. In this regard, it should be noted that the rationale for changing mapping datums at the Federal level relates largely to military considerations, such as missile guidance and satellite surveillance systems, to considerations of intercontinental navigation of both commercial and military aircraft and ocean vessels, and to consideration of scientific research needs where absolute positioning is essential. While these may be important considerations at the national level, they have little bearing on local area mapping or on land and engineering survey operations where relative—as opposed to absolute—positioning is important. Importantly, however, the use of a common datum and projection permits ready correlation of disparate surveying and mapping programs, minimizes the effort required for transformation of data from one datum to another, and reduces confusion in the use of both analog and digital spatial related data.

Certain arguments advanced in support of the conversion to the newer datums either have explicitly stated, or have implied, that the use of the newer datums will in some way result in the preparation of “more accurate” maps. This assertion is patently absurd to anyone knowledgeable about mapmaking. Map accuracy is determined by the specifications to which maps are prepared and by such factors as the scale of the map data compiled and of the map reproduction. Such factors are independent of the coordinate system utilized in the map production.

The quality of spatial information stored in a geographical information system is similarly determined specifically by the precision of the physical measurements added to the database. Deficiencies of any applied computational model, or the datum to which the data are attached, can result in the reduced spatial accuracy of defined points, but the act of expressing results in or attaching spatial measurements to a newer datum does not, in itself, imbue the results with increased accuracy or integrity.

Unless and until the quality of spatial data—both horizontal and vertical—in the existing Commission database is determined to be deficient for the purposes for which it was established—for large-scale topographic and cadastral mapping, the conduct of land and engineering surveys, and the development of parcel-based land information and public works management systems—the fact that more precise spatial data can now be collected and the fact that newer datums have been defined do not constitute compelling reasons to abandon use of the legacy datums in favor of the newer datums. With respect to the use of NAD 83 (2007) for data collection, the mathematical relationship between the two horizontal datums concerned has been determined and documented by the Commission, and users who wish to share compatible horizontal location data may do so efficiently and reliably using those procedures.

Any consideration of conversion is further negated by the frequent adjustment of the newer datums by the National Geodetic Survey (NGS) and by a proposal to adopt an entirely new national positioning datum. Adjustments of the NAD 83 and NAVD 88 datums have resulted in the creation of NAD 83 (1991), NAD 83 (2007), NAD 83 (2011), NAVD 88 (2007), and NAVD 88 (2012). NGS is presently in the process of creating

NAD 83 (2022)[1], and is considering adoption of an entirely new datum—the International Terrestrial Reference Framework datum of 2017 (ITRF-17). The adoption of ITRF-17 would bring with it the use of a new ellipsoid, and would result in a significant shift in horizontal positioning from NAD 83. The need for datum stability for local surveying and mapping application, where relative positioning is more important than absolute positioning, should be apparent.

ESTIMATE OF COSTS TO MIGRATE TO NEWER DATUMS

In spite of the reasons advanced by the Commission for the continued use of the legacy datums within the Region, questions continue to be raised by some but not all practicing surveyors and by some but not all land information system managers as to why the Commission continues to use, and recommends the continued use of, the legacy datums within the Region. Indeed, the Commission convened an interagency staff meeting to address these questions. The meeting was held on November 7, 2011. It was attended by Donald G. Dittmar, Land Information Division Manager, Waukesha County, William C. Shaw, Milwaukee County Automated Mapping and Land Information System Project Manager, Eric Damkot, Geographic Information System Manager, Washington County, Kenneth R. Yunker, Commission Executive Director, Philip C. Evenson, Commission Special Projects Advisor, John G. McDougall, Commission Geographic Information System Manager, and Kurt W. Bauer, Commission Executive Director Emeritus. The consensus reached in the meeting was that the day-to-day operational issues associated with the use of both the new and legacy datums within the Region were not insurmountable, and did not presently impose any significant demand and cost burden on the county and municipal geographic information system staffs. It was nevertheless agreed that it would be helpful to those staffs for the Commission to develop an estimate of the probable costs entailed in the transformation of the existing control survey network and attendant foundational mapping elements to the NAD 83 (2007) and NAVD 88 (2007) datums.

Accordingly, the Commission on December 16, 2011, engaged the firm of Aero-Metric, Inc. to prepare an estimate of the cost that reasonably may be expected to be incurred in a resurvey of the existing control survey network within the seven-county Southeastern Wisconsin Region. The requested cost estimate is presented in a report prepared by Aero-Metric, Inc., which report is provided in Appendix A.

Resurvey Cost Estimate

The estimate of a resurvey of the regional control survey network as provided in the appended report prepared by the firm of Aero-Metric, Inc. may be summarized as:

- Establishment of primary and secondary horizontal control survey network: $2,285,500
- Resurvey of vertical control survey network – Option 2:[2] $4,530,000
- Total: $6,815,500

These costs, expressed in year 2012 dollars, would be incurred over a minimum period of five years. Price inflation at a rate of 2.5 percent per year would bring this total cost to about $7,164,900 over a five-year period.

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[1]*The NGS does not regard the various versions of NAD 83 or NAVD 88 as "new datums." The "datum tag" used is considered by the NGS to identify differing "realizations"—that is, refinements or adjustments—of the datum concerned. From this viewpoint, the first new datum proposed to be introduced by the NGS since the introduction of NAD 83 datum would be the ITRF-17 datum. From the Commission standpoint, the various adjustments of the NAD 83 and NAVD 88 datums are, in effect, new datums since the coordinate position and orthometric height of a monumented survey station would have different values under each adjustment.*

[2]*See Appendix A for descriptions of the two options considered for the vertical control resurvey. Option 2 is the least costly option considered.*

Map Projection and Datums
A resurvey of the regional control survey network would provide, in effect, two of the four foundational elements of a good parcel-based land information or public works management system; namely: 1) a map projection and related datum; and 2) a survey control network that manifests the projection and datum on the surface of the earth. The map projection provided in the Southeastern Wisconsin Region is a Lambert Conformal Conic Projection based upon the Geodetic Reference System of 1980 (GRS 80). The spherical coordinates of this projection are reduced to plane coordinate values by the new State Plane Coordinate System created by the National Geodetic Survey (NGS) for use with the NAD 83 datum. The State Plane Coordinates on the new system are intended to be expressed in meters, while Coordinates on the original State Plane Coordinate System are expressed in U.S. Survey Feet. The map projection for the original system was also a Lambert Conformal Conic Projection based, however, upon the Clarke Spheroid of 1866. The geodetic coordinates of this projection are reduced to plane coordinates by the original State Plane Coordinate system developed by the then U.S. Coast and Geodetic Survey for use with the North American Datum of 1927.

Topographic Maps
A third foundational element of a good parcel-based land information or public works management system is a large-scale topographic map. Ideally, as the resurveys of the horizontal and vertical control survey networks within the Region are completed, new topographic maps would be prepared at a scale of one inch equals 100 feet with a vertical contour interval of two feet. An example of a portion of a topographic map at a scale of one inch equals 100 feet is provided in Figure 1. Examination of Figure 1 will indicate that such maps show such cultural planimetric features as existing buildings, roadway pavements and public sidewalks, driveway pavements and service walks, railway tracks, culverts, power poles, and fence lines; and such natural planimetric features as individual trees, wetlands, and woodlands. The maps show the hypsometry—the elevation and configuration of ground surface—by two foot vertical interval contour lines. These maps are adequate for use in the design of land subdivision plats, for the accurate delineation of drainage areas, for accurate flood hazard area delineation, and for use in the preliminary engineering of public works facilities including roads, sanitary trunk sewers, storm water drainage facilities, and water transmission lines.

These maps provide a good foundational element for the development of matching cadastral maps and for the creation of automated parcel-based land information and public works management systems, particularly in urban areas. These maps should be prepared to meet National Map Accuracy Standards and should be based upon the map projection and datum provided by the resurvey of the horizontal and vertical control survey networks. The maps should be prepared by U.S. Public Land Survey System one-quarter section and should show in their correct location and orientation the section and one-quarter section corners, the State Plane Coordinates of those corners, and the ground level lengths and grid bearings of the one-quarter section lines. The map projection should be shown by grid ticks at a five-inch spacing. These maps provide the essential "ground-truth" for the compilation of the fourth foundational element of good land information and public works management systems.

The cost of the preparation of the topographic maps would vary with the land use pattern of the area to be mapped—urban or rural. In the year 2000, there were, as given in Table 1, 761 square miles of urban development within the seven-county Region, and 1,928 square miles of still remaining rural area. At an estimated cost of $18,000 per square mile for areas in urban use, and $6,000 per square mile for areas in rural use, the cost of the preparation of the topographic maps would approximate $25,266,000. This cost expressed in year 2012 dollars would be incurred over a minimum period of five years. Price inflation at a rate of 2.5 percent per year would bring the total cost to approximately $26,561,300.

Cadastral Maps
The fourth foundational element of a good parcel-based land information or public works management system is a cadastral—real property boundary line—map matching the topographic maps. Like the topographic map, the cadastral map should be compiled by U.S. Public Land Survey System one-quarter section, at a scale of one-inch equals 100 feet, and should be based upon the map projection and datum provided by the resurvey of the control survey networks. The cadastral maps should show in their correct location and orientation the section and one-

Figure 1

PORTION OF TYPICAL LARGE-SCALE TOPOGRAPHIC MAP AT ONE INCH EQUALS 100 FEET

Source: Kenosha County and SEWRPC.

Table 1

LAND USE AREA AND NUMBER OF OWNERSHIP PARCELS IN THE SOUTHEASTERN WISCONSIN REGION 2012[a]

County	Area Square Miles	Land Use Square Miles		Approximate Number of Parcels
		Urban	Rural	
Kenosha	278	64	214	69,670
Milwaukee	242	196	46	259,941
Ozaukee	234	56	178	36,385
Racine	340	79	261	78,680
Walworth	578	73	505	61,296
Washington	436	79	357	53,488
Waukesha	581	214	367	141,169
Total	2,689	761	1,928	700,629

[a]*Land Use Areas are Latest Available: Year 2000.*

Source: SEWRPC.

quarter section corners, the State Plane Coordinates of these corners, and the ground level lengths and grid bearings of the one-quarter section lines. The map projection should be shown by grid ticks at a five-inch spacing. The maps should show in their correct location and orientation the recorded real property boundary lines and the right-of-way lines of all public streets and highways, and of all railway lines. The property boundary corners should be plotted to within one-fortieth of an inch of the record position and any gaps or overlaps between adjoining property boundary lines of 2.5 feet or more and should be shown as mapped lines. The constructed location of the property boundary lines should be checked against the ground-truth provided by the matching topographic maps in the form of building outlines, pavement edges, railway tracks, fences, and stream and water course locations. Figure 2 shows a matching cadastral map for the topographic map provided in Figure 1. The constructed maps are transformed into digital form.

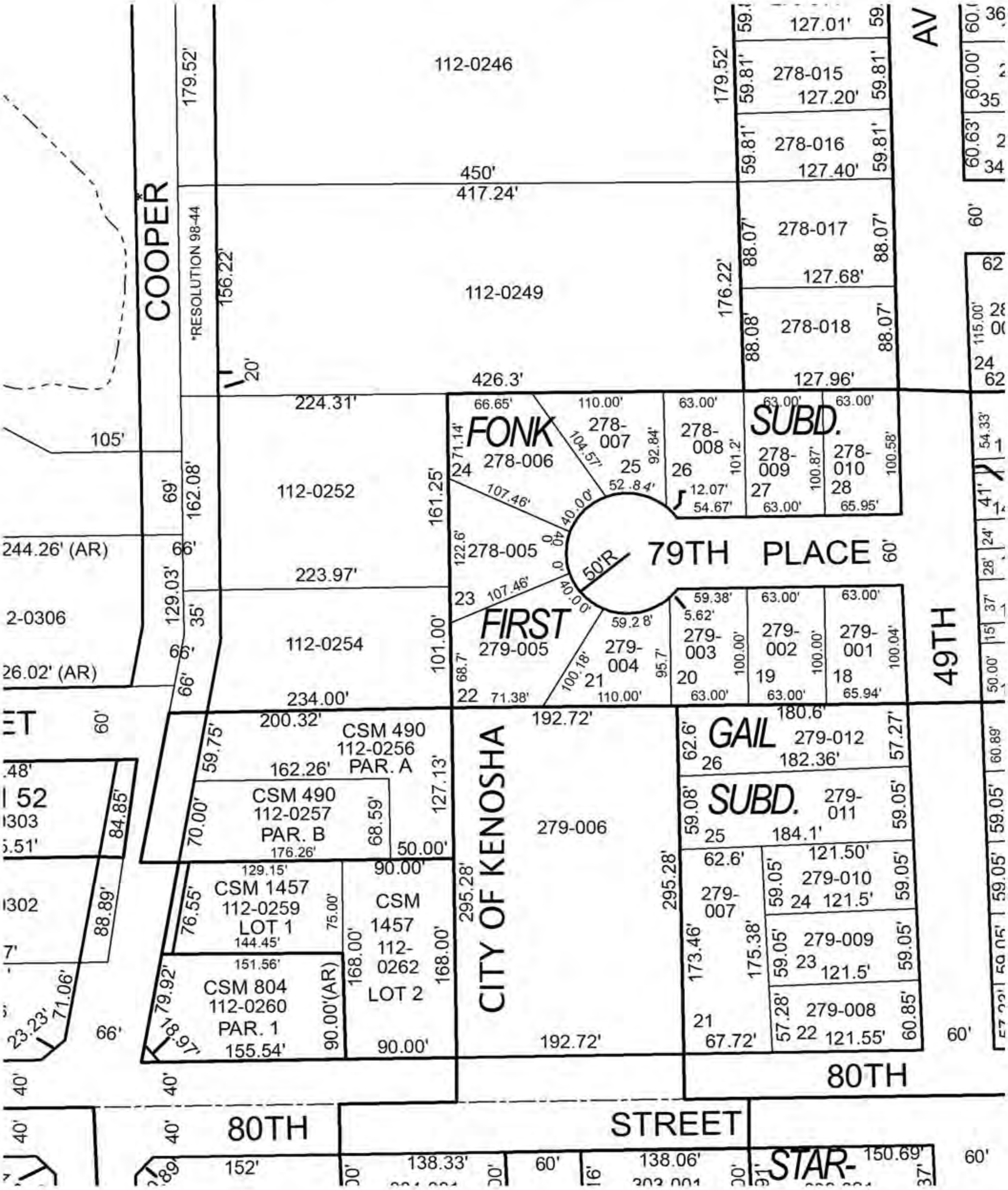
Importantly, the cadastral maps should contain parcel identification numbers which provide the link between digital information stored in the parcel-based land information or public works management system and the geographic location, configuration and areal extent of the attribute data concerned. The data that can be so linked are virtually infinite including, among many others, parcel ownership, assessed valuation, street address, existing and planned land use, soil type and properties, vegetative cover, flood hazard, and zoning. The cadastral maps also provide the basis for the preparation of sanitary sewerage, storm water management, water supply, and other utility system and facility maps, and the linkage of engineering data about these systems and facilities to maps for use in public works management.

It should be noted that a particular feature of the cadastral maps as proposed is not in accord with the basic definition of a map in that the dimensions of the real property boundary lines shown are ground level values, that is, they have not been reduced to grid values. This practice introduces a small difference that can be up to 0.01 foot per 100 feet in the values concerned.

The cost of preparing the new cadastral maps may be estimated at an average of approximately $12 per parcel. As given in Table 1, there were in the year 2012, approximately 700,629 parcels within the seven-county Region, and accordingly, the cost of preparing the new cadastral maps would approximate $8,407,500. This cost expressed in year 2012 dollars would be incurred over a minimum period of five years. Price inflation at a rate of 2.5 percent per year would bring the total cost to approximately $8,838,600.

Figure 2

PORTION OF TYPICAL LARGE-SCALE CADASTRAL MAP AT ONE INCH EQUALS 100 FEET



Source: Kenosha County and SEWRPC.

Summary of Migration Costs

The total cost of migrating the four foundational elements of a good parcel-based land information or public works management system from the legacy to the new datums may thus be expected to approximate $42.56 million, the work being conducted over a five-year period and assuming the production of conventional one-inch equals 100 feet, two foot vertical interval contour maps. The foundational elements provided for this large investment would be of the same, or higher, quality as the elements provided for the existing land information and public works management systems being developed within the Region.

In order to reduce the costs entailed, one-inch equal 100 feet scale orthophotographs could be substituted for the topographic line maps. Two feet vertical interval contour lines obtained by aerial remote imaging—Light Detection and Ranging (LiDAR)—survey could be superimposed upon the orthophotographs thus providing, as do topographic maps, both the hypsometry and the planimetry of an area. The orthophotographs should be prepared with a three-inch pixel size to ensure the sharpest practical delineation of the planimetric features of the area photographed. An example of a portion of a one-inch equals 100 feet scale orthophotograph utilizing a three-inch pixel size is provided in Figure 3**.** Examination of Figure 3 will indicate that orthophotographs show, in effect, all of the planimetric details of the area photographed, although some of the details may be obscured by shadows. In some areas the detailed configuration of such details as pavement edges may lack the definitive delineation shown on line maps. Moreover, the definitive identification of some features such as power and light poles, culverts, and fence lines—and even building outlines—may require substantial skills in aerial photo-interpretation. With the availability of such skills, however, these orthophotos may be put to the same, but not all, uses as the comparable line maps.

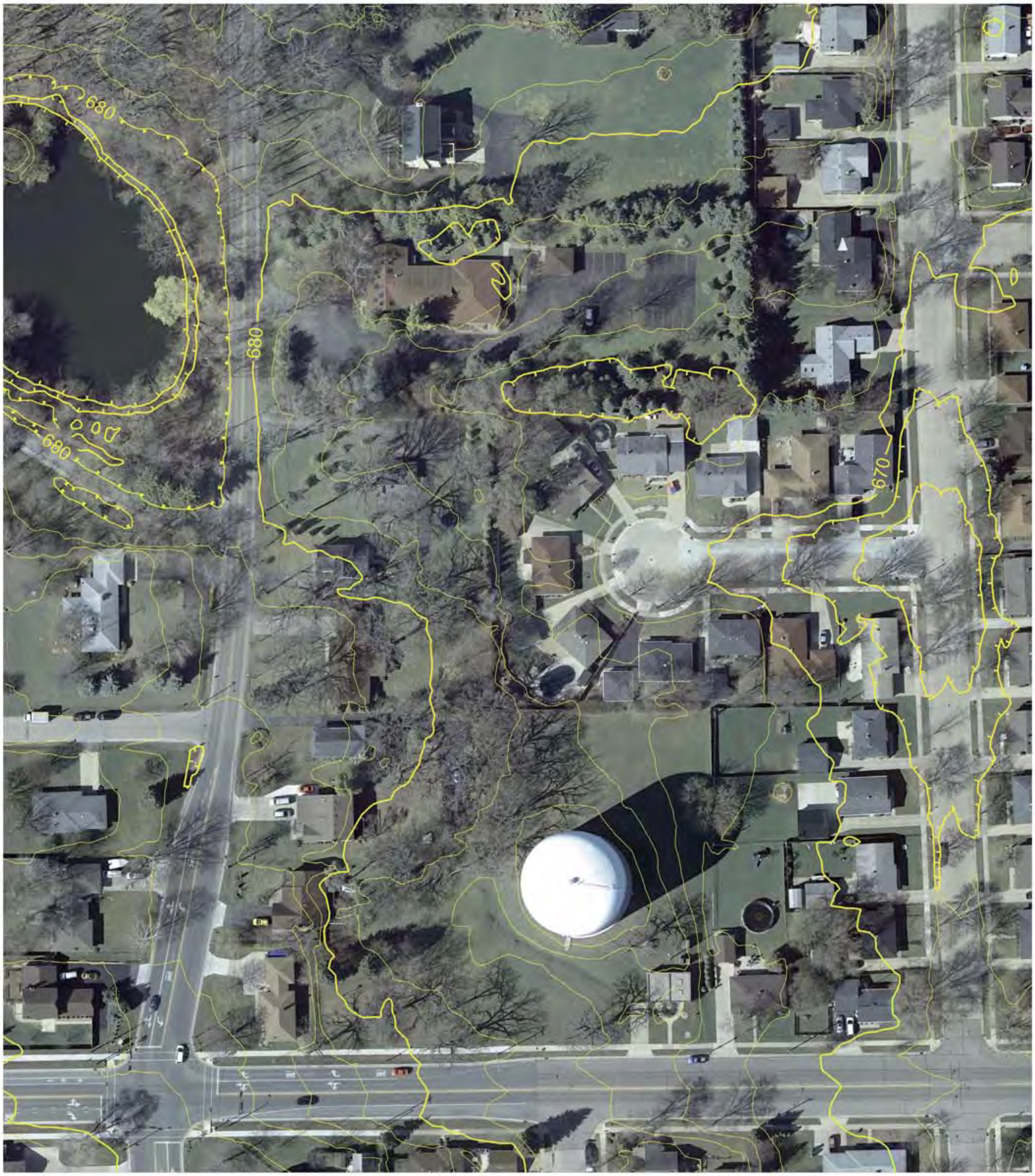
The cost of the type of orthophotographs recommended may be expected to approximate $1,795.00 per square mile, or $4,827,000 for the entire Region, expressed in 2012 dollars. The cost would be incurred over a minimum period of five years. Price inflation at a rate of 2.5 percent per year would bring the total cost to approximately $5,074,200. The cost of the third foundational element could thus be reduced from the approximately $26.56 million cost of new conventional topographic mapping, to approximately $5.07 million, a reduction of approximately 81 percent**.** The most readily quantifiable differences between the use of line maps and orthophotographs are related to post acquisition processing cost. Other differences, however while intangible may be more important, and relate to the cost effectiveness, as opposed to processing cost, of the products. These differences relate to the innate characteristics of the two types of products, and concern the usefulness of the products for some applications. These intangible differences have not been addressed, to date, in the professional literature concerning the use of maps and orthophotographs in the development of land information and public works management systems.

Properly prepared, orthophotographs can meet the same accuracy standards as line maps for features located at ground level. Features on orthophotographs such as the roof lines of buildings and bridges which are above ground level may be displaced. The identification of certain kinds of features such as power and light poles, fence lines, culverts, and even sometimes building outlines may, as already noted, be left to the user, but require the application of aerial photo-interpretation skills. Moreover, the plethora of detail on an orthophotograph may actually be a disadvantage for some uses since the features shown are not differentiated with respect to the importance of the features for an intended use. For this reason, the use of orthophotographs in the preparation of the plan portion of public works construction plans and profiles has been found by some engineers and agencies to be less satisfactory than the use of line maps.

In the preparation of the line maps the necessary aerial photo-interpretation is accomplished by experienced photogrammetrists, and the resulting product is not only more definitive than comparable orthophotography, but also more useful for some applications since the maps emphasize the features important to those applications. Moreover, the differing details shown on line maps may be maintained in a database in separate digital layers. Such differentiation may be useful for certain engineering applications, as for example, in the design of storm water management systems. In such design the proportion of a catchment area covered by impervious surfaces is an important consideration, and this proportion can be readily and accurately determined by computer

Figure 3

PORTION OF AN ORTHOPHOTOGRAPH UTILIZING A THREE-INCH PIXEL AT
ONE INCH EQUALS 100 FEET WITH TWO-FOOT VERTICAL CONTOUR INTERVAL LINES



Source: Kenosha County.

manipulation of the digital data on a layered line map. Because of the definitive nature of line maps, such maps are also better suited as a foundational element for public works management systems than are orthophotographs.

Other Map Transformation Alternatives
The bidirectional transformation procedures and equations developed by the Commission permit the transformation of survey data collected using the newer horizontal and vertical datums such as NAD 83 (2007) and NAVD 88 (2007) to the legacy datums. Those procedures and equations also permit existing attribute data residing within the land information system to be transformed to the newer datums for use. Such transformation of attribute data is also possible utilizing a number of transformation programs currently available from both public and private sources. The commercially available software most commonly used within the Region for the transformation of spatial data between datums is that provided by Environmental Systems Research Institute, Inc. and known as ESRI ArcGIS. Other such software programs include Intergraph GeoMedia, Blue Marble Geographic Calculator, and FME Spatial Data Transformation. The software vendors indicate that transformations between NAD 27 and NAD 83 utilizing these programs may be expected to have mean errors of approximately 0.2 meter, adequate for land information system purposes, but not for land and engineering survey purposes. Software known as NADCON—available from the National Geodetic Survey (NGS) permits the conversion between the legacy and new horizontal datums at a mean error of approximately 0.15 meter. Software—known as VERTCON—available from the NGS permits the conversion between the new and legacy vertical datums at a mean error of approximately 0.02 meters, adequate for land information system purposes and for some land and engineering survey purposes. The Commission equations set forth in SEWRPC Technical Report No. 49 provide equivalent or better levels of accuracies in the transformations concerned.

EMERGING ISSUE

Technically, the legacy datums in use within the Region clearly can serve indefinitely as essential components of the foundational elements of the parcel-based land information systems that have been or are being developed within the Region. The ability to make bidirectional transformations between these legacy and the newer datums, combined with the ability of newer survey techniques to provide accurate State Plane Coordinate values referred to the legacy datum, permit the continued use of the legacy datums for both the collection and dissemination of attribute data for use in comprehensive physical planning and municipal engineering. Consequently, no compelling reasons exist to abandon these legacy datums for newer datums with respect to the relatively stable—or static—control survey, topographic and cadastral map, and related attribute data such as parcel street address location, ownership, assessed valuation, land use, zoning, soils, vegetation, floodland and wetland, and other similar types of planning and engineering data. These types of data usually change slowly over time. The data bases concerned are usually updated only periodically, and the procedures permit application of the available bidirectional transformation equations to effect any occasional needed shifts in the datums concerned.

There may be, however, an emerging need to provide spatial location information for virtually real-time applications. Such applications are beginning to be used by police, fire protection, emergency medical service, arterial street and highway traffic management, and transit service providers utilizing GPS technology. This technology permits the identification of the spatial location of conditions and incidents—such as an accident—and the location of service vehicles—such as police patrol cars and transit buses on a real-time basis. The various types of GPS equipment used provide geographic positions relative to the NAD 83 datum with the locations being displayed relative to some kind of map showing the public street and highway network and the street address data embedded in the map. The legacy foundational elements for the more stable, or static, parcel-based land information systems do not appear suitable for use with these emerging dynamic applications given the datum differences and the need for rapid transformations between datums.

There are a number of emergency management dispatch centers currently in operation within the Region. These centers utilize computer-aided dispatch (CAD) software which generally contains default base maps, including street centerlines and related reference features. Some CAD systems include address ranges whereby the location of specific incidents can be interpolated along street centerline segments. The default base maps generally do not contain and display a high level of detail with respect to specific street address locations and specific building locations. Some dispatch centers have chosen to augment the default base map layers with large-scale digital maps—more accurate street centerlines, parcel lines, address points, and orthophotography—compiled on the NAD 27 datum. The most common CAD system in use in the Region—Phoenix CAD from ProPhoenix, Inc. headquartered in New Jersey—converts all data imported into the system to the World Geodetic System of 1984 (WGS 84) reference framework, the same system of reference used for global positioning systems. Data in this system uses a latitude and longitude coordinate system. Incorporating digital data into such systems involves a conversion effort, but often this is accomplished by software without operator interaction. Ultimately, data in the commercial systems and data in land information systems are not immediately integrated in real time. This lack of integration creates the need to find a way to utilize the land information system maps as the maps utilized by the emergency management systems.

Potential Resolution

If total conversion of the developing land information systems and the supporting control survey network within the Region from the legacy datums to the new datums is concluded to be impractical and unnecessary, a potential solution to the issue raised might be the creation of a new set of foundational elements supplementing the legacy foundational elements in use within the Region. The new set of foundational elements would be concerned only with horizontal positioning, and would be based upon NAD 83. This new set of foundational elements would be utilized for the spatial location and plotting of the types of dynamic real-time attribute data desired by the police, fire protection, emergency medical service, arterial street and highway traffic management, and transit service providers within the Region utilizing GPS technology to establish coordinate values for the phenomena concerned. This second "dynamic" system would be maintained and used in parallel with the "stable" existing systems intended to serve comprehensive planning and municipal engineering applications.

These "dynamic" systems should not require the same level of accuracy in horizontal and vertical positioning as do the "static" existing systems with their supporting control survey networks. Consequently, it should be possible to use either the Commission's equations, or one of the commercially available software programs, to create the new foundational elements for the "dynamic" systems. If it is assumed that cadastral maps and the street address data embedded in the maps would provide an adequate foundation for the "dynamic" systems, then only the cadastral maps residing in the existing legacy systems would need to be transformed to fit the new datum—NAD 83. Transformation of the topographic maps and control survey network data comprising two of the three foundational elements would not be necessary.

There appear to be at least two means of providing a foundational element for the dynamic systems. One of these involves the acquisition and use of one of the commercially available digital base maps specifically designed and provided for use by a dynamic real-time system. This means is apparently in wide-spread use within the Region by agencies such as police and fire departments and for navigational systems installed in vehicles. These systems rely upon the collection of attribute data by global positioning system technology and are, therefore, related to the newer datums.

The second means of providing the foundational element for a dynamic system would be transformation of the legacy cadastral maps from the legacy horizontal datum to the NAD 83 datum. This conversion could be done either by use of commercially available software such as ESRI ArcGIS, or by application of the Commission's equations. Conceptually, such transformation would be accomplished by the transformation of the property boundary corners plotted on the cadastral maps from one datum to the other, and then the completion of the map by an automated drafting program. Undertaking either of these transformations presumes that, for whatever reasons, the commercially available digital base maps are deficient for comprehensive public use.

The accuracy of the two transformed maps should be evaluated by field measurement in terms of the ability to meet the requirements of dynamic user applications. Computer software may have to be developed to facilitate the conversion using the Commission equations. The practicality of the application with respect to computer time and, therefore, cost required for the transformations would be determined as part of a pilot program. A pilot study would also formulate the positional accuracy standards to meet the transformed cadastral maps in order for such maps to be suitable as a foundation for a dynamic system.

SUMMARY AND CONCLUSIONS

The recommendations of the Commission with respect to the continued use of the NAD 27 and NGVD 29 datums within the Region have served well the land information system, land survey, and public works engineering communities within the Region from 1961 to the present. The control survey network based upon these datums, together with the attendant topographic and cadastral maps, have provided a sound foundation for the development of automated parcel-based land information and public works management systems within the Region by the Commission and its constituent counties and municipalities. The control survey network has also provided a sound basis for the conduct of land and engineering surveys within the Region, and for the periodic preparation of areawide aerial orthophotography. The integration of the control survey network and the topographic and cadastral maps achieved within the Region provides a unique and extraordinarily effective foundation for the parcel-based land information systems being developed and used within the Region. This integration permits the ready acquisition and incorporation of attribute data typically required for comprehensive physical planning and municipal engineering into the land information systems. It similarly provides for the update of the cadastral maps of such systems through the ready incorporation of new subdivision plats and certified survey maps. This integration also provides for the development, maintenance, and use of public works management systems within the Region, such systems being separate from, but complementary to the land information systems. The introduction of the newer survey technologies—specifically Global Positioning System (GPS) and Continuously Operating Reference Station (CORS) technology—present no problems for the continued use of the legacy datums within the Region.

The Commission staff has demonstrated that it is possible to utilize GPS technology cost-effectively and the existing CORS network established within the Region by the WisDOT to obtain accurate State Plane coordinate values in the NAD 27 datum. Moreover, the Commission has provided a detailed example of how GPS technology and the WisDOT CORS system can be used to obtain accurate coordinate values of survey points on the NAD 27 datum. This example is set forth in Appendix G of SEWRPC Technical Report No. 49, *Bidirectional Transformation of Legacy and Current Survey Control Data Within Southeastern Wisconsin*, May 2010.

In spite of the foregoing rationale advanced by the Commission for the continued use of the legacy datums within the Region, questions continued to be raised by some practicing surveyors and by some land information system managers as to why the Commission continues to use and recommends the continued use of the legacy datums within the Region. In response to these questions, the Commission engaged the firm of Aero-Metric, Inc. to prepare an estimate of the cost that may be reasonably expected to be incurred in a resurvey of the existing control survey network within the Region in order to base that network upon the new datums introduced by the Federal government. The cost estimate so prepared is presented in a report prepared by Aero-Metric, Inc., which report is provided in Appendix A. That report estimates the cost of such a resurvey, if carried out over a five-year period, at approximately $7.16 million, assuming that Option 2 of the resurvey of the vertical network is chosen for a vertical component.

The resurvey would provide only two of the four foundational elements of a good parcel-based land information or public works management system; namely: 1) a map projection and related datum; and 2) a survey control network that manifests the projection and datum on the surface of the earth. The resurvey would place these two elements on the new NAD 83 (2007) datum and would do so with as high, or higher an accuracy level, than the legacy control survey network within the Region.[3] Two additional foundational elements would, however, also

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[3]*The land information managers concerned specifically requested that the desired cost estimate be made for the migration of the existing control survey network within the Region from the legacy datums to the NAD 83 (2007) and NAVD 88 (2007) datums. The costs presented in this report are applicable to the migration of the legacy datums in use within the Region to any of the NAD 83 and NAVD 88 realizations. It is not known at this time if those costs would also apply to the proposed ITRF-17 datum. The different datum realizations and the new datum would provide different coordinate values and different elevations between the datum realizations and the new datum as well as between the various datum realizations and new and the legacy datums.*

Table 2

COST SUMMARY OF ALTERNATIVE APPROACHES TO PREPARING REPLACEMENT LAND INFORMATION SYSTEM (LIS) FOUNDATIONAL ELEMENTS FOR THE REGION UNDER NEW DATUMS[a]

LIS Foundational Elements	Conventional 1"= 100′ Scale Topographic Mapping	3" Pixel Orthophotography With 2′ Contour Intervals
Resurvey of Horizontal and Vertical Networks	$ 7,164,900	$ 7,164,900
Topographic Mapping	26,561,300	- -
Orthophotography With Contour Intervals	- -	5,074,200
Cadastral Mapping	8,838,600	8,838,600
Total	$42,564,700	$21,077,700

[a]*All costs based on 2012 unit costs inflated over a five-year production period.*

[b]*Cost for the Resurvey of the Vertical Network assumes the use of Option 2 of the vertical component.*

Source: SEWRPC.

have to be transformed to fit the new datum; namely: 1) large-scale topographic maps meeting National Map Accuracy Standards; and 2) matching large-scale cadastral maps meeting a comparable level of accuracy. The cost of preparing the new topographic maps over a five-year period is estimated at about $26.56 million. The cost of preparing the new cadastral maps over a five-year period is estimated at approximately $8.84 million, bringing the total cost of providing the four foundational elements, to the same or higher quality as the elements provided for the legacy systems, to approximately $42.56 million (see Table 2). By substituting less desirable orthophotographs for the topographic maps, this total cost could be reduced to about $27.08 million, or by about 50 percent.

This substantial cost entailed in providing new foundational elements, would not include the cost of transforming the attribute data presently contained within the land information and public works management systems being developed within the Region from the legacy to the new datums. Such transformations would be possible through application of the bidirectional transformation equations developed by the Commission, or by the application of commercially available software programs. The use of such transformation methodologies might also be considered to provide the two base map elements of the four foundational elements described above. The transformed base maps may not meet National Map Accuracy Standards for the topographic maps, nor the compatible accuracy standards for the cadastral maps, thus, destroying the integrity provided by the legacy systems.

It is highly unlikely at this time that funding of the very large costs associated with a datum transformation within the Region could be obtained. Even if such funding could be obtained, however, a transformation would not necessarily be in the public interest. Good public administration practice requires that it be shown that the benefits derived from a potential investment exceed the costs entailed. To date, none of the proponents of a datum transformation within the Region have provided evidence of any significant monetary benefits that might accrue from the transformation. The Commission decision to continue to use the legacy datums within the Region, and to recommend the continued use of those datums to the county, municipal and special purpose government agencies operating within the Region, is reaffirmed.

APPENDICES

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Appendix A

AERO-METRIC REPORT ON COST OF RESURVEY OF SEWRPC CONTROL SURVEY NETWORK

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4020 Technology Parkway
Sheboygan, WI 53083
P: 920.457.3631
F: 920.457.0410
www.aerometric.com

REPORT ON COST OF RESURVEY OF SEWRPC CONTROL SURVEY NETWORK

General

The Southeastern Wisconsin Regional Planning Commission has established an extensive and accurate network of horizontal and vertical control survey stations on 11,985 U.S. Public Land Survey System (USPLSS) corners throughout the seven-county Southeastern Wisconsin Region.

The State Plane Coordinates of the horizontal network are related to the North American Datum of 1927 (NAD 27) achieving Third-Order, Class I accuracy and specifications. The elevations of the vertical element which consists of a minimum of one reference bench mark for each USPLSS corner are based upon the National Geodetic Vertical Datum of 1929 (NGVD 29) achieving Second-Order, Class II accuracy.

The use of Global Positioning System (GPS) technology and new national datums have made the previously established control difficult to reference using current surveying procedures. Elaborate computations are required to relate the two horizontal and two vertical datums to one another. A local governmental agency has requested the Commission to investigate the cost associated with establishing North American Datum of 1983-2007 (NAD 83 (2007)) coordinates and North American Vertical Datum of 1988 (NAVD 88 (2007)) elevations for all 11,985 USPLSS corners and ancillary bench marks within the region. In response to this request, the Commission requested the firm of Aero-Metric, Inc. to prepare an estimate of the cost of a resurvey of the horizontal positions of all USPLSS corners based upon the NAD 83 (2007). The resurvey would at a minimum meet Order C (former First Order) standards and specifications. The resurvey would also determine orthometric heights – elevations – for at least one bench mark for each monumented USPLSS corner and the corner itself, based upon the NAVD 88 (2007) datum. The vertical control surveys would meet or exceed Second Order, Class II standards.

Primary Horizontal Control Network

The first phase of a proposed horizontal control resurvey would establish a Primary Network. The Primary Network would consist of the USPLSS Township Corners, including correction corners, throughout the region. If the USPLSS Township Corner cannot support a direct occupation a USPLSS corner nearest the Township Corner would be selected and observed.

This Primary Network would require the occupation of all 107 township corners. Observations at these corners would be made simultaneously in groups designed to achieve closed high order configurations, the groupings always including in addition to the township corners one or more of the Continuously Operating Reference Stations (CORS) of the Wisconsin Department of Transportation CORS network in the area. Thirty-minute simultaneous static observation sessions by the groups of township corners incorporating the CORS network in the processing would be required. The observations would provide coordinate positions for the occupied stations by reference to Global Positioning System (GPS) satellites. As observed, these positions would be expressed in terms of latitude and longitude, and would then be converted to State Plane Coordinates expressed in meters based upon the NAD 83 and the State Plane Coordinate system provided by the National Geodetic Survey. The coordinate positions would be further converted to feet based upon the U.S. Survey Foot. It should be noted that the differences between NAD 83 and NAD 83 (2007) would be considered insignificant for these purposes and therefore ignored in the computations. These positions would then be converted to vectors connecting the stations and forming a network amenable to adjustment by least squares computation. The basic control would be provided by the CORS network in the area, and the published coordinate values of the CORS stations would be held fixed in subsequent network adjustment computations. The resurvey would follow Wisconsin Department of Transportation (WisDOT) Standards and Specifications for Global Positioning System (GPS) Surveys in Support of Transportation Improvement Projects, as revised in 2005. These standards and specifications are appended to this report. The proposed accuracy would achieve 1:250,000 (Order B, Class III).

The purpose of the proposed Primary Network would be to support all the subsequent horizontal control surveys by minimizing any distortion errors in localized secondary control surveys. Exhibit A indicates the proposed groupings of the observation control survey sessions anticipated to establish the Primary Network within the region.

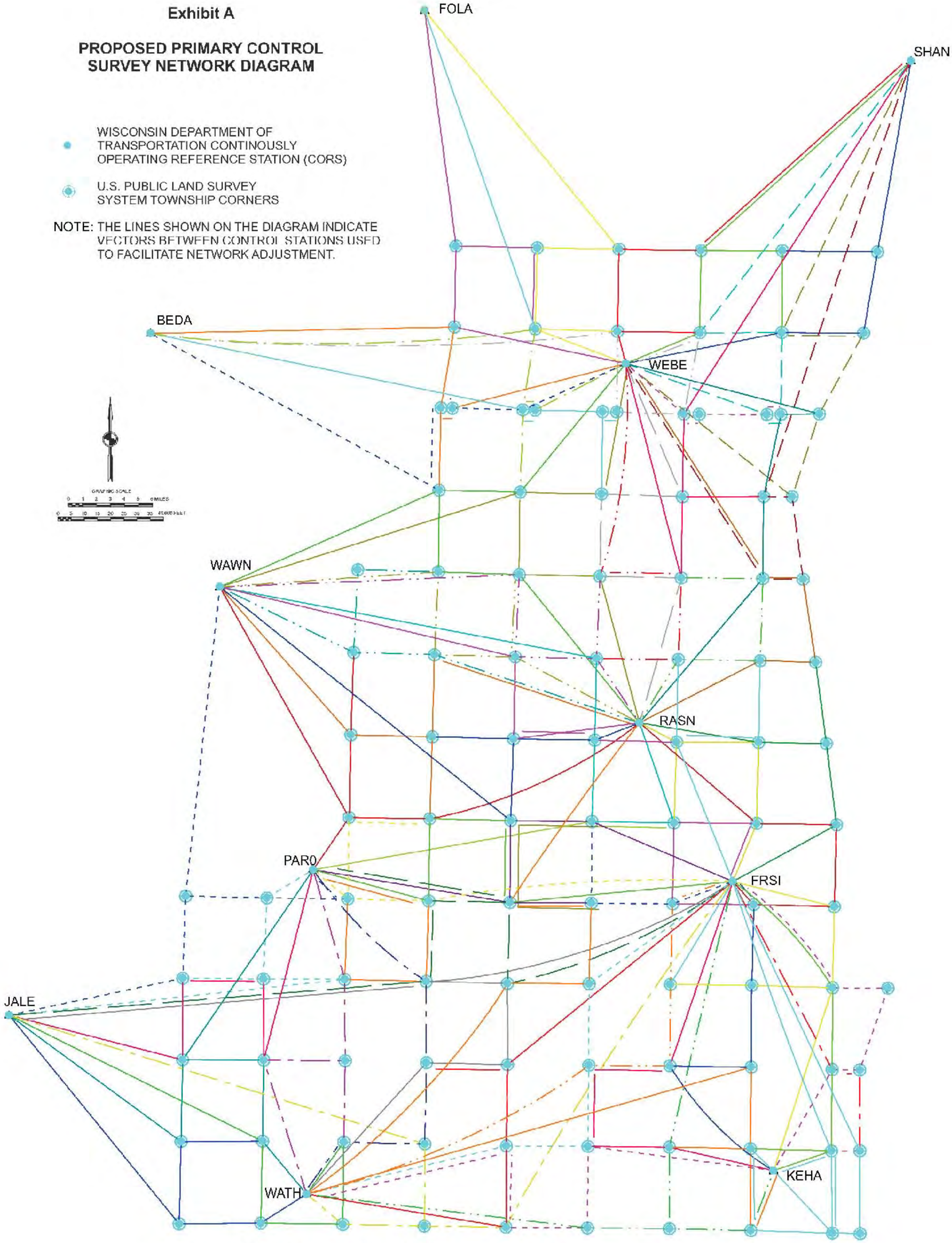
Secondary Horizontal Control Network

The second phase of the proposed horizontal control resurvey would establish a Secondary Network. This phase would include the recovery and use of USPLSS corners, including section, one-quarter section, center of section, meander, and witness corners as stations in the network. In total the Commission maintains 11,985 USPLSS corners. The secondary resurvey would be conducted by township blocks to ensure the timely completion and delivery of new horizontal control information over the course of the project. Priority of delivery would be based on the direction of the Commission.

All of the 11,985 USPLSS corners within the region would be recovered and surveys would be completed to determine the coordinates of the corners and the lengths and bearings of all the quarter-section lines. Using the positions of the township corners, a minimum of two base stations would also be established within each

Exhibit A

PROPOSED PRIMARY CONTROL SURVEY NETWORK DIAGRAM



Source: Aero-Metric, Inc. and SEWRPC.

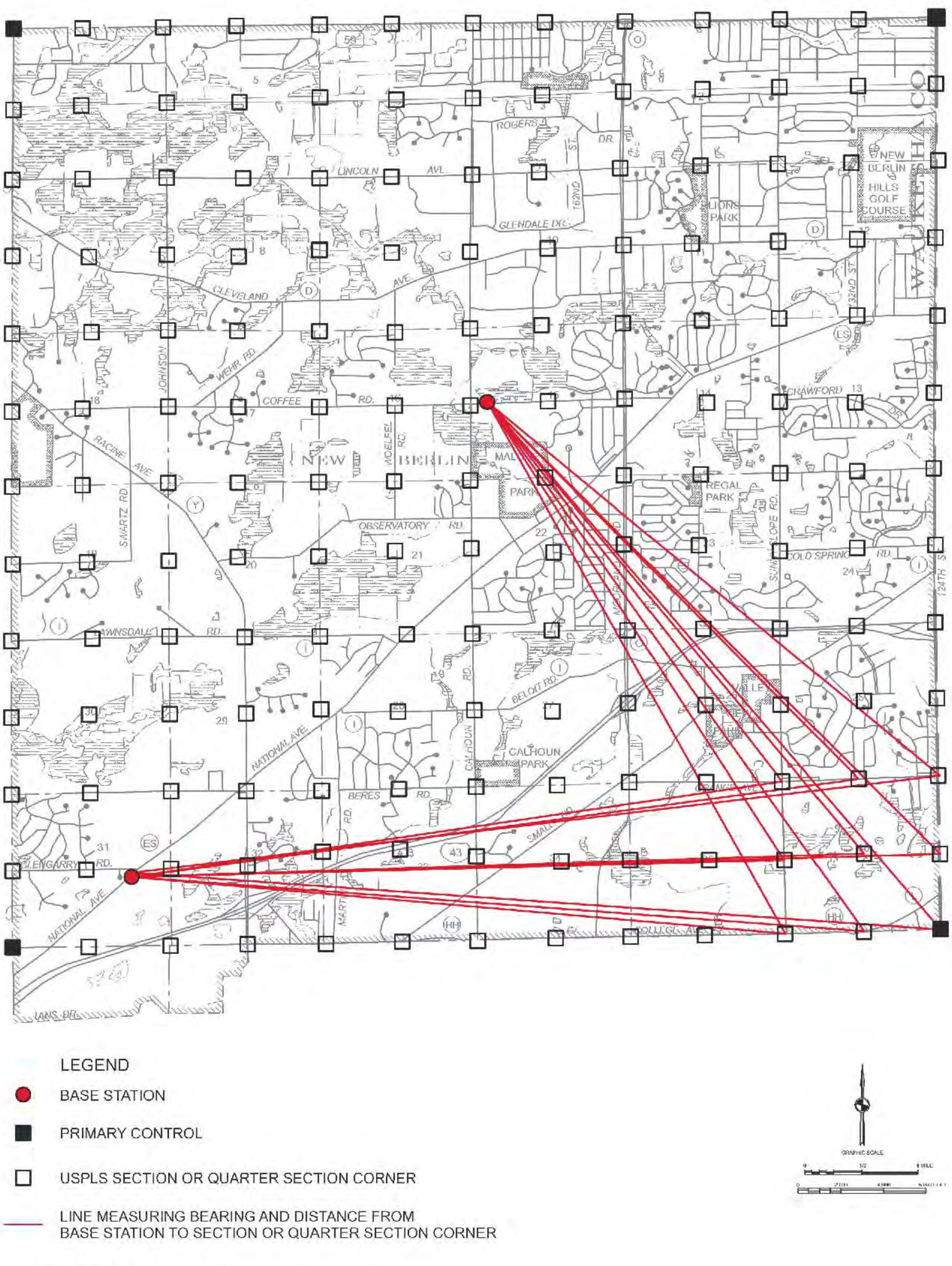
township. These base stations would be established to facilitate the observations that would be made simultaneously at the base stations and at each of the section, quarter-section, center of section, meander, and witness corner within the township. The observations would provide coordinate positions for the base stations and USPLSS corners by reference to the GPS satellites. As observed, these positions would be expressed in terms of latitude and longitude, and would then be converted to State Plane Coordinates expressed in meters based upon the NAD 83 and the State Plane Coordinate system based upon that datum provided by the National Geodetic Survey. The coordinate positions would be further converted to feet based upon the U.S. Survey Foot. It should be noted that the differences between NAD 83 and NAD 83 (2007) would be considered insignificant for these purposes and therefore ignored in the computations. These positions would then be converted to vectors connecting the township corners, base stations, and USPLSS corners for use in adjustment computations. All coordinates would be based upon the Wisconsin State Plane Coordinate System, South Zone, NAD 83; and sufficient survey connections would be made to the Primary Network—the township corners—to permit the proper checks and adjustments to be made as required to achieve the desired level of accuracy for each monumented USPLSS corner. The coordinates would be expressed in feet – not meters as envisioned by the National Geodetic Survey. The Secondary Horizontal Control surveys would utilize GPS technology to determine the coordinates of the monumented corners and the lengths and bearings of the quarter-section lines. This would require approximately 200 observations in a typical full township, consisting of the 169 section and quarter-section corners. Approximately 30 redundant observations would also be required to validate the desired accuracy. The observations at the corners would be made simultaneously with observations at the base stations and at the township corners, and would occupy about 10 minutes at each corner.

The accuracy of the horizontal control surveys would meet Order C (former 1st Order) accuracy as set forth in the WisDOT Standards and Specifications for Global Positioning System (GPS) Surveys in Support of Transportation Improvement Projects, 23 October 1996 (revised 4 January 2005). All field measurements would be adjusted by National Geodetic Survey (NGS) methods to provide closed traverses before traverse station and USPLSS corner coordinates are computed, and attendant lengths and bearings of the quarter-section lines are computed so as to form closed geometric figures for the quarter-sections.

Exhibit B indicates a sample baseline diagram to illustrate the second phase resurvey of the USPLSS corners within a typical Township.

Exhibit B

PORTION OF A GPS BASELINE SURVEY PROPOSED TO BE USED TO OBTAIN NAD 83 (2007) COORDINATE VALUES FOR USPLSS CORNERS WITHIN A TOWNSHIP



Source: SEWRPC.

Survey Computation Data and Plats

All field notes and office computations would be kept in a neat and orderly manner, clearly indexed, and open for inspection and checking during the course of the work. Upon completion and acceptance, all field notes and computations would be furnished to the Commission and become Commission property. Instruments and assistance would be provided to a duly authorized agent of the Commission for such checking of field work and computations as may be deemed necessary by the Commission.

1. A dossier would be prepared for each control survey station (USPLSS corner) on 8-1/2 inch by 11 inch stable base material. Exhibit "C" attached hereto illustrates the required form and content of these dossiers. The following information would be provided for each station on the dossiers:

    a. Title giving the description of the control survey stations (USPLSS corners). The stations would also be identified by assigned numbers.

    b. A sketch, showing the monumented control survey station in relation to the salient features of the immediate vicinity. Witness monuments and bench marks set would be shown together with their measured ties to the station. A north point properly positioned thereon. The names of adjoining streets, state trunk highways, or public land would be indicated. The bearing and distance to one other control station from the station would also be shown.

    c. The coordinates of the station.

    d. The Elevation of the USPLSS corner and at least one ancillary bench mark

    e. The angle between geodetic and grid bearing at the station (theta angle).

2. One azimuth mark would be set for each control survey station (USPLSS corner) surveyed. The azimuth mark could be an adjacent USPLSS corner, or some other well-defined, permanent, distant object of the landscape that can be clearly identified and described. Where it is not possible or practical to use such an object, a commercial survey monument of a design approved by the Commission would be substituted.

Exhibit C

EXAMPLE OF RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

RECORD OF U. S. PUBLIC LAND SURVEY CONTROL STATION

U. S. PUBLIC LAND SURVEY CORNER 24|24 / 25|25 T 5 N, R 21 E, MILWAUKEE COUNTY, WISCONSIN

HORIZONTAL CONTROL SURVEY BY: AERO-METRIC ENGINEERING, INC. YEAR: 1993
VERTICAL CONTROL SURVEY BY: SEWRPC YEAR: 2007

STATE PLANE COORDINATES OF: QUARTER SECTION CORNER
NORTH 324,725.89
EAST 2,546,528.32
ELEVATION OF STATION: 728.007

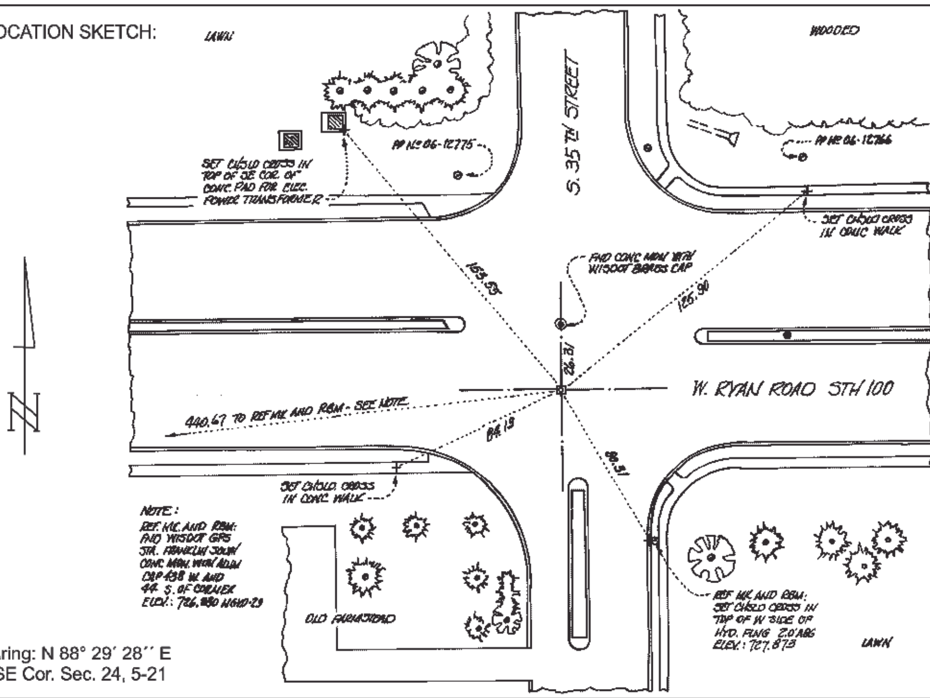
HORIZONTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, SOUTH ZONE
NORTH AMERICAN DATUM OF 1927

ALL MEASUREMENTS AND COORDINATES EXPRESSED IN U.S. SURVEY FEET

VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929 THETA ANGLE: +1° 24′ 03′′

CONTROL ACCURACY:
HORIZONTAL: THIRD ORDER, CLASS I VERTICAL: SECOND ORDER, CLASS II

LOCATION SKETCH:



Bearing: N 88° 29′ 28′′ E
To SE Cor. Sec. 24, 5-21

SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN)
MILWAUKEE COUNTY) SS

As Milwaukee County Surveyor, I hereby certify that following highway reconstruction, I set a concrete monument with SEWRPC brass cap to mark the location of this corner; replacing a concrete monument with cast iron plug with cross found and referenced by me as Milwaukee County Surveyor on September 11, 1992; said concrete monument with cast iron plug having been set to mark the location of this corner in 1941 by E.G. Plautz, State Highway Commission of Wisconsin Project Engineer, following highway reconstruction; replacing a cast iron plug with cross set in the then existing concrete pavement to mark the location of this corner in 1916 by a Milwaukee County Highway Department Project Engineer, following highway reconstruction; replacing an old cut limestone monument set to mark the location of this corner in 1878 by Jonathan C. Crounse, Surveyor, in the conduct of the remonumentation of the Town of Franklin; replacing in turn a wood post set to mark this corner in May 1836 by Elisha Dwelle, Deputy United States Surveyor, in the conduct of the original United States Public Land Survey; that I have referenced the same as shown hereon; and that this record is correct and complete to the best of my knowledge and belief

WISCONSIN K. W. BAUER S-157 MILWAUKEE, WI LAND SURVEYOR

DATE OF SURVEY: 30 August 2007 Kurt W. Bauer
REGISTERED LAND SURVEYOR S - 157

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION 106

Vertical Control Surveys – Option 1

The vertical control survey would be based upon NAVD 88 (2007) as established by the NGS. As already noted, at least one ancillary bench mark has been established by the Commission for each monumented USPLSS corner. The Vertical Control resurvey would be completed by USPLSS Township blocks to ensure the completion and timely delivery of the vertical control information over the course of the project.

Closed digital bar coded spirit-level circuits would be run to the established bench mark in the project area. The spirit-level circuits would meet Second-Order Class II accuracy as set forth in "Standards and Specifications for Geodetic Control Networks" prepared by the Federal Geodetic Control Committee. A copy of these standards are appended to this report. All level circuits would be adjusted for closure by NGS methods. Elevations would be obtained for the 11,985 monuments marking USPLSS corners and for at least one ancillary bench mark for each corner as established by the Commission. In addition, elevations would be obtained for bench marks set along the spirit-level lines on such objects as bridge abutments and wing walls, headwalls of large culverts, water tables of large buildings, outcroppings of ledge rock, or other stable objects which are unlikely to be displaced vertically.

At least one bench mark would be established for, and tied horizontally to, each USPLSS corner monument and would be set so that the elevation of the corner monument may be readily verified from the additional permanent bench mark by a single spirit-level position.

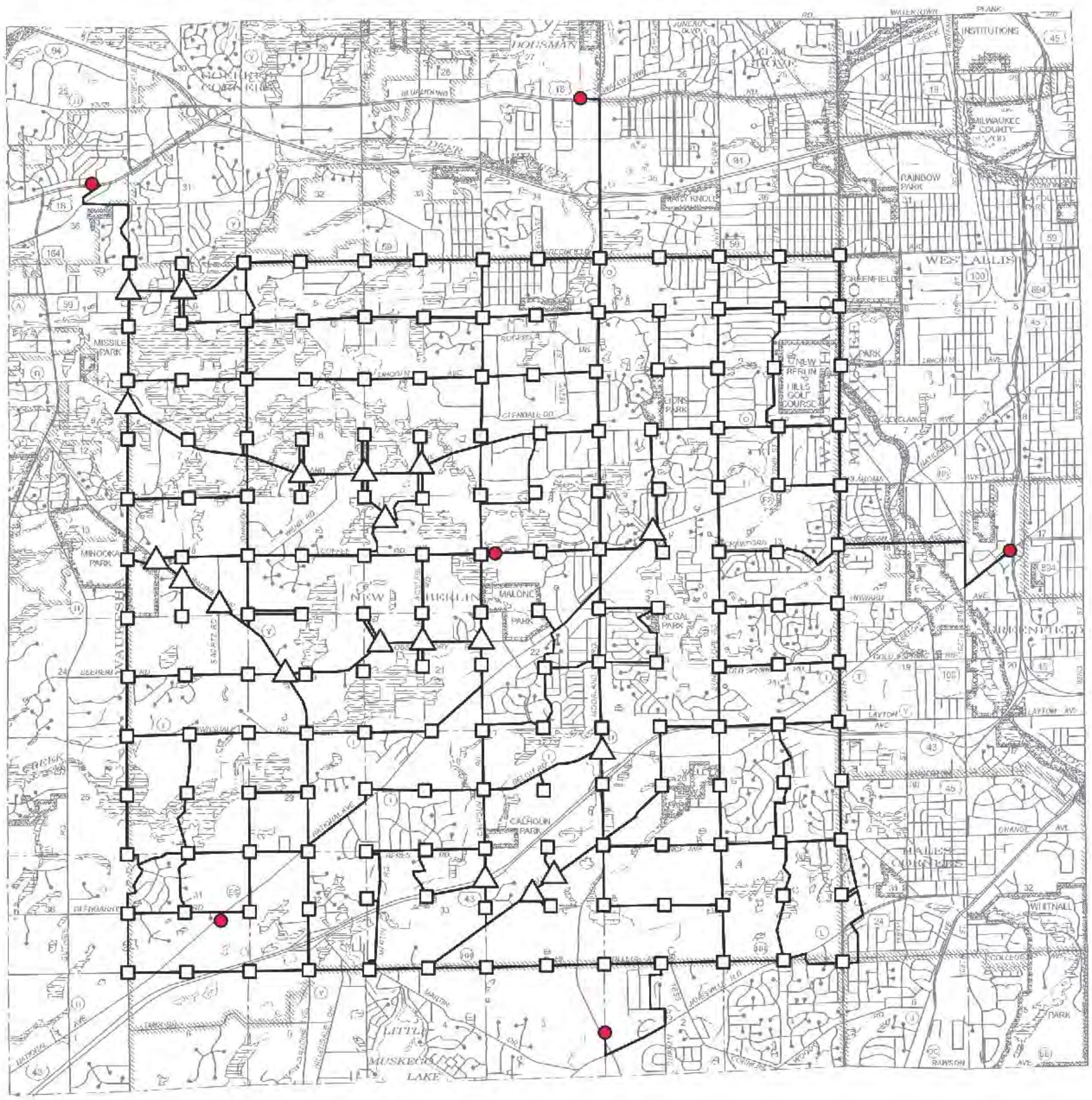
Survey Computation Data and Plats

All field notes and office computations would be kept in a neat and orderly manner, clearly indexed, and open for inspection and checking during the course of the work. Upon completion and acceptance, all field notes and computations would be furnished to the Commission and become Commission property. Before final acceptance of the work instruments and assistance would be provided to a duly authorized agent of the Commission for such checking of field work and computations as may be deemed necessary by the Commission.

Exhibit D shows, as an example, a proposed circuit within a survey township that would tie the elevations of the USPLSS corner monuments and ancillary bench marks to existing Wisconsin Height Modernization monuments that would be used as a basis of the vertical control surveys.

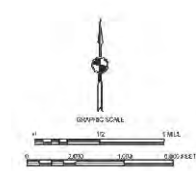
Exhibit D

EXAMPLE OF A VERTICAL CONTROL SURVEY LEVEL CIRCUIT TO OBTAIN NAVD 88 (2007) ELEVATIONS OF USPLSS CORNER AND ANCILLARY BENCH MARKS



LEGEND

- ● WISDOT HEIGHT MODERNIZATION STATION
- □ USPLSS SECTION OR QUARTER SECTION CORNER
- —— HIGH-ORDER SPIRIT LEVEL CIRCUIT LINE
- △ SUPPLEMENTARY BENCHMARK LOCATIONS



Source: SEWRPC.

Vertical Control Survey – Option 2

In the alternative to Option 1, GPS technology would be used to resurvey the vertical control survey network. The GPS measurements made for each USPLSS corner under the Horizontal Secondary Network resurvey would be used to determine orthometric height—elevations—for each control survey station (USPLSS corner). These ellipsoid height measurements together with an applied latest NGS geoid and the differences in elevations between neighboring USPLSS corners as determined by historic Commission spirit-level surveys would be used to determine an orthometric elevation vertical height—for each observed USPLSS corner. The differences found between adjacent USPLSS corners as determined from the GPS observations would be compared to the differences found between the existing spirit-leveled differences as determined by the original Commission control surveys, as published on the NGVD 29. If the GPS determined differences were found to meet Second-Order, Class II accuracy the NGVD 29 difference would be used as an additional constraint in a final least squares adjustment. If the difference were found to be outside of Second Order, Class II accuracy, the corner concerned would require a new digital bar-code spirit-level run to determine a new elevation and resultant difference. This would also be compared to the GPS measurement and if within acceptable tolerance used as part of the vertical constrained adjustment. If still outside of the limit, the GPS measurement would be ignored and the elevation for the corner accepted using the digital bar-code spirit-leveled solution.

Deliverables

Upon completion of the resurvey the Engineer would deliver to the Commission the following items:

- One control station dossier sheet for each of the 11,985 control survey stations (USPLSS corners) and ancillary bench marks.
- The original field notes and computations prepared under the resurvey.
- A summary of the findings of the resurvey documenting an approximately 469 control survey summary diagrams. Each diagram is to cover an area consisting of six USPLSS sections—and is to show the State Plane Coordinates of the monumented stations referred to the NAD 83 (2007), the grid and ground-level lengths and grid bearings of the one-quarter section lines, the elevations of the monumented stations referred to NAVD 88 (2007), the interior angles of the one-quarter Sections, the area of the one-quarter sections in ground-level acreage, the difference between grid and geodetic north, and the combination scale and sea level reduction factor applicable at the center of each six-section diagram. The Coordinates are to be expressed in U.S. Survey feet, not meters. A typical control survey summary diagram is provided in Exhibit E.

Cost Estimate

The anticipated cost of each phase of the resurvey work described above is estimated to be as follows:

- Establishment of Primary Horizontal Network - $55,500.00
- Establishment of Secondary Horizontal Network - $ 2,230,000.00
- Resurvey of Vertical Network—Option 1 – $ 6,772,000.00
- Resurvey of Vertical Network Option 2 - $ 4,530,000.00

The estimates provided are based upon average survey costs as of calendar year 2012. Table 1 provides a summary of the basis of the cost estimates set forth above.

The significance and complexity of this resurveying program would be enormous. The locations of these USPLSS Corners should be given special consideration and proper planning will be vitally necessary for a successful completion of this program. It would be the opinion of Aero-Metric that a minimum of 5 years based on the level of effort necessary to complete the field observation, the office reduction of the measurements, and finalization of all project deliverables.

Exhibit E

EXAMPLE OF CONTROL SURVEY SUMMARY DIAGRAM

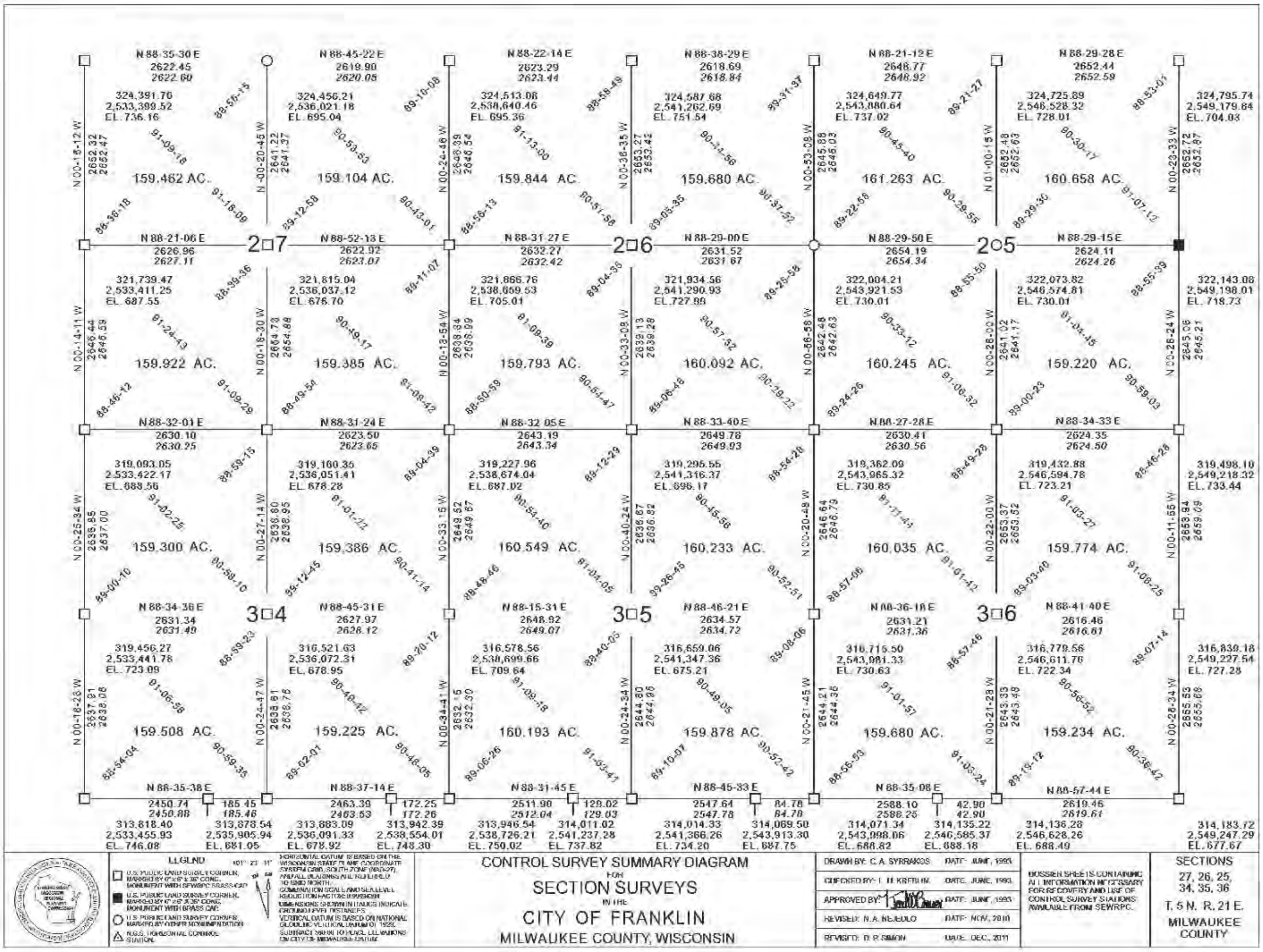


Table 1

BASIS OF COST ESTIMATES

Establishment of Primary Network

Description	Personnel Hours	Cost Breakdown
Field Work	420	$46,800.00
Office Reduction	64	$ 6,700.00
Project Management	16	$ 2,000.00
Total	--	$55,500.00

Establishment of Horizontal Secondary Network

Description	Personnel Hours	Cost Breakdown
Field Work	12,907	$1,651,500.00
Office Reduction	5,531	$442,500.00
Project Management	1,134	$136,000.00
Total	--	$2,230,000.00

Vertical Network (Option 1)

Description	Personnel Hours	Cost Breakdown
Field Work	52,690	$6,011,440.00
Office Reduction	7,380	$590,400.00
Project Management	1,418	$170,160.00
Total	--	$6,772,000.00

Vertical Network (Option 2)

Description	Personnel Hours	Cost Breakdown
Field Work	14,892	$1,721,680.00
Office Reduction	31,912	$2,552,960.00
Project Management	2,128	$255,360.00
Total	--	$4,530,000.00

The budgetary fee estimates indicated above are based upon average survey costs as of calendar year 2012.

Source: Aero-Metric, Inc.

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FIRST APPENDIX TO AERO-METRIC, INC. REPORT
WISDOT HORIZONTAL SURVEY CONTROL SPECIFICATIONS

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Wisconsin Department of Transportation
Guidelines on Standards and Specifications For Global Positioning System (GPS) Surveys in Support of Transportation Improvement Projects

DRAFT

23 October 1996 (revised 04 January 2005)

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Disclaimer

The distribution and use of this document does not constitute, in any way, an endorsement by the Wisconsin Department of Transportation. The distribution and use of ***this document is intended only for the purpose of providing the user, guidelines for planning and execution of geodetic surveys*** *relative to a High Accuracy Reference Network using GPS technology.*

Table of Contents

1. Purpose

This document provides technical standards, specifications, guidance, and quality control criteria for performing Global Positioning System (GPS) surveys in support of photogrammetric mapping and engineering activities.

2. Reference(s)

a. Challstrom, C. W., 1991: Federal Geodetic Control Classification Standards Revision for Network Upgrades, GIS/LIS 1991.

b. Hoyle, D., 1992: Unpublished Correspondence, St. Paul, MN.

c. Hull, W. V., (Federal Geodetic Control Subcommittee), 1988, (Reprinted 1989): Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, National Geodetic Information Center, NOAA, Silver Spring, MD.

d. Rapp, R. H., 1984: Geometric Geodesy Part 1, The Ohio State University, Department of Geodetic Science and Surveying, Columbus, OH.

e. Wisconsin Department of Transportation, 1992: Request For Proposal on Establishment of a High Precision Geodetic Network Using GPS Technology for Dodge, Jefferson, and Rock Counties, WI, Madison, WI.

3. Applicability

This document applies to all Bureau Offices, Districts, and consultants performing surveys with the Global Positioning System (GPS) in support of geodetic, engineering and photogrammetric mapping activities.

4. Reconnaissance

A number of factors affect the performance of GPS and the final coordinate position. These factors include the following:

- Setup errors (pole tips and level/data collector) bracket.
- Obstructions.
- Satellite geometry.
- Observation time.
- Resolution of correct set of integer ambiguities (initialization).
- Topography (range of communication link).
- Weather.
- Field survey procedures.
- Quality of control stations.
- Equipment configuration.
- Radio frequency interference.

Site selection is a key element in reducing the time required for planning GPS surveys and post-processing and analyzing GPS observational data. The following guidelines shall be used for determining the optimal location of newly established survey stations and the potential use of existing stations:

- At normal antenna height, having a clear view above 15 degrees above the horizon for 360 degrees in azimuth.
- Where not likely to be disturbed.
- On stable ground.
- Readily accessible by vehicle.
- Avoid tall artificial and natural reflective structure or surfaces that would project above the antenna ground plane.
- Anticipate future road construction and tree growth.
- Provide adequate site distances for conventional survey methods.
- Adhere to airport requirements.
- Ensure safety of surveyors and others.
- Avoid radio towers, high transmission lines, and other sources of radio frequency (RF) interference.
- Off of the traveled portion of a road but within highway right-of-way or other public property (e.g., parks).
- In the event power lines are not avoidable, place on the opposite side of the road from power lines such that the lines are below 15 degrees above the horizon.

5. Standards

Standards are utilized to classify the accuracy of the survey. Standards consist of position closure requirements and relative error ellipse values (line accuracies). Standards are driven by the project requirement and not the technology. Before a survey is certified it must satisfy the Relative Line Accuracy (RLA) requirements set forth in Table 1. B Order geometric accuracy standards were subdivided into three classes of 1, 2, and 4 ppm (Challstrom, 1991 and WIDOT, 1992) (Table 1). These additional orders of accuracies bridge the gap between the FGCS B and First Order accuracy standards. The survey control established under the guidance of these standards and specifications is not intended to be incorporated into the National Geodetic Reference System (NGRS).

Table 1 - Geometric Relative Positioning Accuracy Standards

Application	Conventional Accuracy Classification		Maximum Allowable Error (s)[a]		Proposed FGCS Accuracy Classification
	Order	Class	Base Error (m)	ppm	
Densification of HARN - Multi County	B	I	0.008	1	2 cm
Densification of HARN - County	B	II	0.008	2	2 cm
Densification of HARN - Township	B	III	0.008	4	2 cm
Geodetic Surveys (Engineering and Project)	First		0.010	10	5 cm
Section Corners	Second	I	0.010	20	1 dm
Section Corners and Photogrammetric Targets	Second	II	0.010	50	1 dm
Local Control	Third		0.010	100	2 dm

5.1. Table 1 - Legend

HARN: High Accuracy Reference Network
m: meters
ppm: parts per million (mm/km)
mm: millimeters
cm: centimeter
dm: decimeter
m: meter
km: kilometers

5.2. Table 1 - Footnotes

a: All connected and unconnected baselines (vectors) within the minimally constrained and constrained network adjustments shall comply with the 3-D relative positional error (s) required for the desired classification.

$$s = \sqrt{e^2 + (d * p * 10^{-6})^2}$$

s = Maximum allowable relative positional error (m) at the 95% (2σ) confidence level.
e = Base error in meters (m)
p = ppm for that classification (e.g. B Order, Class II, 2 ppm)
d = Distance in meters (m)

6. Specifications

Specifications are the procedures and processing guidelines that must be followed in order to satisfy a specific accuracy Classification. Specifications evolve with technology and the development of innovative techniques. The specifications were subdivided into data acquisition, data analysis, and data submittal sections.

6.1. Data Acquisition Specifications

Different GPS survey techniques (e.g. static, rapid/fast static, etc.) can be utilized with these specifications. Specifically, each technique is described as follows:

Static Relative Positioning Technique:

- Most reliable of all relative positioning techniques.
- Using dual-frequency receivers, the technique is applicable for A- through third-orders of accuracy.
- Using single-frequency receivers, the technique is applicable for first- through third-orders of accuracy.
- Consists of at least two receivers remaining stationary during the observation period.
- Requires simultaneous observation of a minimum of four common satellites at two or more stations to obtain reliable resolution of integer ambiguities.
- Occupation time at station(s) is dependent on distance between stations, ionospheric activity, and model of GPS receiver. An approximate guideline for occupation times for static positioning is approximately 60 minutes for every 10 km of distance separating the stations.

Rapid/Fast Static Relative Positioning Technique:

- This technique is applicable for first- through third-orders of accuracy.
- Consists of at least two receivers remaining stationary or one receiver remaining stationary and one (or more) receivers roving during the observation period.
- Requires simultaneous observation of a minimum of five common satellites at two or more stations to obtain reliable resolution of integer ambiguities.
- Occupation time at station(s) is dependent on distance between stations, and model of GPS receiver. Occupation times at station(s) may vary between 5 and 30 minutes.
- Generally is effective for baseline distances less than 25 km.

Kinematic Relative Positioning Technique:

- This technique is applicable for second- and third-orders of accuracy.
- Consists of one or more receivers remaining stationary and one or more receivers roving during the observation period.
- Requires lock on a minimum of five satellites.
- Depending on the GPS receiver hardware, firmware, and software, loss of lock can be tolerated since this technique is capable of determining the integer ambiguities instantaneously.
- Occupation time at remote station(s) is generally a few seconds to a few minutes.
- Generally is effective for areas with no visual obstructions projecting more than 15 degrees above the horizon.

Table 2 illustrates the suggested guideline for the order of accuracy and specification.

Table 2 - GPS Relative Positioning Data Acquisition Specifications

Specifications	B Order			First Order	Second Order		Third Order
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
1. Horizontal Control 1. Minimum number of connections to known control	3[a]	3[a]	3[a]	3[a]	3[a]	3[a]	3[a]
2. Vertical Control 1. Minimum number of connections to known control	5[b]	5[b]	5[b]	5[b]	4[b]	4[b]	4[b]
3. Station Spacing 1. Minimum station spacing (km) 2. Maximum station spacing (km)	20[c] 50[c]	10[c] 20[c]	3[c] 10[c]	0.4[c] 10[c]	0.15[c] 5[c]	0.15[c] 3[c]	0.15[c] 1[c]
4. Location of Known Control 1. Number of quadrants relative to the center of the project	4	4	4	3	3	3	3
5. Dual Frequency Observations (L1 and L2) Required	Y[d]	Y[d]	Y[d]	Y[d]	OP[d]	OP[d]	OP[d]
6. Required Number of Receivers Observing Simultaneously (not less than)	4	4	4	3[e]	2	2	2
7. Satellite Observations 1. Geometric Dilution of Precision (GDOP)	MG[f]	MG[f]	MG[f]	MG[f]	MG[f]	MG[f]	MG[f]
2. Period of observation session required	MG[g]	MG[g]	MG[g]	MG[g]	MG[g]	MG[g]	MG[g]
3. Number of satellites tracking simultaneously continuously during entire session	5	5	5	5	5	5	5

Table 2 - GPS Relative Positioning Data Acquisition Specifications

Specifications	**B Order**			**First Order**	**Second Order**		**Third Order**
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
4. Number of quadrants signals shall be available during entire observing session	3	3	3	3	3 or 2[h]	3 or 2[h]	3 or 2[h]
5. Maximum angle (degrees) above horizon for obstructions	20	20	20	20	20-40	20-40	20-40
6. Minimum observation angle (degrees)	15	15	15	15	15	15	15
7. Data sampling rate (sec)	MG[i]	MG[i]	MG[i]	MG[i]	MG[i]	MG[i]	MG[i]
8. Re-observation times must differ	Y[j]	Y[j]	Y[j]	Y[j]	Y/OP[j]	Y/OP[j]	Y/OP[j]
8. Independent Occupations per Station 1. Three or more (percent of all known and new stations, not less than)	20[k]	20[k]	20[k]	10[k]	0	0	0
2. Two or more (percent of new stations, not less than)	50[l]	50[l]	50[l]	30[l]	30[l]	30[l]	30[l]
3. Two or more (percent of known vertical control stations, not less than)	100[k]	100[k]	100[k]	100[k]	100[k]	100[k]	100[k]
4. Two or more (percent of known horizontal control stations, not less than)	50[m]	50[m]	50[m]	30[m]	30[m]	30[m]	30[m]
5. Between occupations, tripod must be removed and reset	Y	Y	Y	Y	Y	Y	Y
6. Two or more occupations on all stations (reference - azimuth stations or eccentric stations)	Y	Y	Y	Y[n]	Y[n]	Y[n]	Y[n]
7. At least two independent vectors required for each station	Y	Y	Y	Y	Y	Y	Y

Table 2 - GPS Relative Positioning Data Acquisition Specifications

Specifications	B Order			First Order	Second Order		Third Order
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
9. Repeat Baselines 1. Approximate equal number in N-S and E-W directions, minimum not less than (percent of independent baselines)	5[o]	5[o]	5[o]	5[o]	OP[o]	OP[o]	OP[o]
2. Repeat baseline measurements for station pairs (reference-azimuth stations or eccentric stations)	Y	Y	Y	Y[n]	Y[n]	Y[n]	Y[n]
10. Antenna Set-up 1. Number of antenna phase center height measurements per session, not less than	2[p]	2[p]	2[p]	2[p]	2[p]	2[p]	2[p]
2. Tribrachs and/or other centering devices shall be checked and adjusted	Y[q]	Y[q]	Y[q]	Y[r]	Y[r]	Y[r]	Y[r]
3. Height of Instrument (HI) in metric and English	Y[s]	Y[s]	Y[s]	Y[s]	Y[s]	Y[s]	Y[s]
4. Independent plumb bob check required	Y[t]	Y[t]	Y[t]	Y[t]	OP	OP	OP
11. Photograph and Pencil Rubbing Required	Y[u]	Y[u]	Y[u]	Y[u]	OP	OP	OP
12. Meteorological Observations Required	Y[v]	Y[v]	Y[v]	Y[v]	Y[w]	Y[w]	Y[w]
13. Field Data Logs Required	Y[y]	Y[y]	Y[y]	Y[y]	Y[z]	Y[z]	Y[z]
14. Maximum Elevation Angle (degrees) Between Operator and/or Vehicle and Antenna	5	5	5	5	5	5	5

6.1.1. Table 2 - Legend

Y:	Yes (required)
OP:	Optional
MG:	Manufacturers Guidelines
m:	meters
km:	kilometers
ppm:	parts per million

6.1.2. Explanation of Table 2 (Specifications, Footnotes, Discussion and Examples)

Specification: 1. Horizontal Control.

1. Minimum number of connections to known control.

Footnote: a: ***The minimum number of horizontal control connections is three (3) for all Orders of accuracies. The connections between the control stations and unknown stations shall be formed to ensure that all control stations influence (through direct or indirect observations) the unknown stations.*** Two survey techniques (network, traverse) are used to ensure redundancy and increase reliability of the survey. The network or traverse should consist of a minimum of three known horizontal control stations.

- *Network.* A network consists of a closed polygon where vectors (baselines) connect known and unknown stations. The known control stations should be situated in different quadrants (cardinal directions) relative to the center of the project. The network method is required for B and First Order surveys and optional for all other order surveys.
- *Traverse*. Traverses are an effective method of establishing engineering quality survey control for transportation projects. A minimum of three known stations is required when performing a traverse. Two of the known stations form the beginning and the terminus of the traverse line. The third known station should be located perpendicular to the traverse line and near the center of the project area. The traverse method is an optional approach to Second and Third Order surveys.

The known stations must be of equal or greater classification (B, First, Second, Third Order) than the control that is to be established. The known control stations can be "acceptable" Wisconsin Department of Transportation (WIDOT), National Geodetic Survey (NGS), County or United States Army Corps of Engineers (USACE) control.

Discussion: Depending upon the accuracy standard a minimum of three (3) control stations shall be used to control the network to be surveyed. When possible, other control stations should be used to assist in strengthening the network and isolating errors between control stations and observations. The known stations must be of equal or greater classification (B, First, Second, Third Order) than the control that is to be established. The known control stations can be "acceptable" WIDOT, NGS, County, or USACE control. Two survey techniques (network and traverse) are used to ensure redundancy and increase reliability of the survey. It is not advisable to use the "rover" survey technique where one (1) or more base stations are established and one (1) rovers are used to position section corners. This "rover" survey technique does not provide adequate connections between stations, which weakens network geometry and hence blunders and/or errors are not adequately detected.

Example: To be included at a later date.

Specification: 2. Vertical Control.

<u>1. Minimum number of connections to known control.</u>

Footnote: b: The vertical control must be distributed in a least three quadrants relative to the center of the project. ***The establishment of vertical control using GPS is currently a developmental effort and should be used with caution for production purposes.***

Discussion: Depending on the accuracy standard the specification requires a minimum of four (4) vertical control stations, which must be distributed in a least three quadrants relative to the center of the project. The accuracy of the orthometric heights established will be dependent upon the number of vertical control stations (i.e. benchmarks), accuracy of previously derived orthometric height, availability of an accurate geoid model, and size of project area in relation to existing vertical control.

Example: To be included at a later date.

Specification: 3. Station Spacing.

<u>1. Minimum station spacing (km) and 2. Maximum station spacing (km).</u>

Footnote: c: Depending on the application, the user may need to extend the distance to achieve required positional accuracy for Second and Third Order.

Discussion: The specification requires that stations be established at specific intervals to satisfy relative line accuracy requirements.

Example: To be included at a later date.

Specification: 4. Location of Known Control.

<u>1. Number of quadrants relative to the center of the project.</u>

Footnote: Not applicable.

Discussion: The specification requires known control to be equally distributed in three quadrants relative to the center of the project. This will ensure proper network geometry.

Example: To be included at a later date.

Specification: 5. Dual Frequency Observations (L1 and L2) Required.

Footnote: d: Dual frequency observations are required for all baselines in excess of 10 km. When performing surveys using the rapid/fast static technique the user must follow the equipment and software guidelines of the manufacturer.

Discussion: This specification is required to reduce the effect of error caused by ionospheric refraction.

Example: Not applicable.

Specification: *6. Required Number of Receivers Observing Simultaneously (not less than).*

Footnote: e: When reference - azimuth stations or eccentric stations are observed the requirement is two (2) receivers.

Discussion: The specification requires a minimum of four (4), three (3) and two (2) GPS receivers observing simultaneously for B Order, Class I through B Order Class III, First Order and Second Order through Third Order accuracies respectively. For Second and Third Order accuracies three (3) receivers is more practical and four (4) receivers is more efficient for production.

Example: Not applicable.

Specification: *7. Satellite Observations.*

1. Geometric Dilution of Precision (GDOP).

Footnote: f: The GDOP should follow manufacturer's guidelines.

Discussion: The specification suggests the user follow the manufacturer's guidelines for GDOP.

Example: Not applicable.

2. Period of observation session required.

Footnote: g: The period of the observation session is dependent upon the receiver manufacturer recommendations, distance (length) between stations and the user's experience with their hardware, firmware, and post-processing software.

Discussion: The specification does not require a specific amount of time over the mark for recording observations. The period of the observation session will be dependent upon the receiver manufacturer recommendations and the user's experience with their hardware, firmware, and post-processing software.

Example: Depending on the GPS hardware, firmware and software, and the distance between observing stations observation times can range from 2 minutes to several hours. For example, a 1 ppm survey with baselines up to 50 km should observe satellites for approximately 2.5 - 4 hrs or with baselines up to 2 km should observe up to 5 minutes.

3. Number of satellites tracking simultaneously continuously during entire observing session.

Footnote: Not applicable.

Discussion: This specification ensures an adequate number of satellites in the event signals are pre-empted because of blockage.

Example: Not applicable.

4. Number of quadrants signals shall be available during entire observing session.

Footnote: h: Satellites should pass through quadrants diagonally opposite each other (FGCC, 1988)

Discussion: To be completed at a later date.

Example: Not applicable.

5. Maximum angle (degrees) above horizon for obstructions.

Footnote: Not applicable.

Discussion: Depending on the accuracy standard the specification requires that obstructions be 20-40 degrees or less above the horizon. The specification ensures that the user does not observe in heavily obstructed areas however, judgment should be used in determining if quality data can be obtained. As an example, it might be permissible to observe a mark if no satellites are in the area of the obstruction.

Example: Not applicable.

6. Minimum observation angle (degrees).

Footnote: Not applicable.

Discussion: The specification requires a minimum observation angle of 15 degrees. Most manufacturers do not recommend tracking satellites below 15 degrees.

Example: Not applicable.

7. Data sampling rate (sec).

Footnote: i: The data sampling rate will be dependent on the manufacturer's guidelines.

Discussion: The specification requires the user to follow the recommendations of the manufacturers. This rate can be either 5, 10, 20, or 30 seconds depending upon the survey technique used.

Example: As an example, a 5 second recording interval is used for fast/rapid static positioning techniques.

8. Re-observation times must differ.

Footnote: j: Re-observation times must differ by tracking a constellation that includes a minimum of two (2) different satellites, which were not tracked in the previous occupation. In addition, the observation times between occupations must differ by at least one (1) hour. The processing of session observational data shall include all satellites with only satellites that present problems be deleted. For First Order, this requirement only applies to azimuth marks established with HARN densification stations.

This specification must be satisfied when kinematic relative positioning techniques are used for Second and Third Order surveys.

Discussion: The specifications do require a separation between the times of re-occupation of the stations. It is recommend in order to satisfy the Independent Occupations specification that the user occupy the mark approximately an hour or more later to ensure a change in the constellation.

Example: As an example, if stations 101, 102, 103 and 104 are occupied from 1000 - 1130 hours of Day 1 then each of those stations can be occupied after 1230 hours of Day 1 to satisfy this specification.

Specification: 8. Independent Occupations per Station.

1. Three or more (percent of all known and new stations, not less than).

Footnote: k: The number (i.e. three or more and two or more) of independent occupations per stations shall be equally distributed throughout the project area.

Discussion: This specification ensures the survey network has adequate redundancy and uniformity, and with assisting in isolating blunders and/or errors.

Example: As an example, using B Order Class II (2 ppm), if a project has 5 known stations and 10 new (unknown) stations, then the percent of three or more occupations would equal (5 + 10) * .20 (i.e. 20%) = 3 stations. Therefore, 3 stations (known, new or combination thereof) shall be occupied at least three or more times and be equally distributed throughout the project area.

2. Two or more (percent of new stations, not less than).

Footnote: l: The number (i.e. two or more) of independent occupations per stations shall be equally distributed throughout the project area. For kinematic positioning techniques the requirement is 100%.

Discussion: This specification ensures the survey network has adequate redundancy and uniformity, and with assisting in isolating blunders and/or errors.

Example: As an example, using Second Order, Class II (50 ppm), if a project has 28 new (unknown) stations, then the percent of two or more occupations would equal (28) * .30 (i.e. 30%) = 8.4 or 9 stations. Therefore, 9 stations (new) shall be occupied at least two or more times and be equally distributed throughout the project area.

3. Two or more (percent of known vertical control stations, not less than).

Footnote: k: The number (i.e. two or more) of independent occupations per stations shall be equally distributed throughout the project area.

Discussion: This specification ensures the survey network has adequate redundancy and uniformity, and with assisting in isolating blunders and/or errors. In addition, the specification ensures that a higher order of accuracy can be achieved in elevation.

Example: For all Orders of accuracies each vertical station must be occupied at least two times.

4. Two or more (percent of known horizontal control stations, not less than).

Footnote: m: The number (i.e. two or more) of independent occupations per stations shall be equally distributed throughout the project area. For kinematic positioning techniques the requirement is 50%.

Discussion: This specification ensures the survey network has adequate redundancy and uniformity, and with assisting in isolating blunders and/or errors.

Example: As an example, using Second Order, Class II (50 ppm), if a project has 5 known stations, then the percent of two or more occupations would equal (5) * .30 (i.e. 30%) = 1.5 or 2 stations. Therefore, 2 stations (known) shall be occupied at least two or more times and be equally distributed throughout the project area.

5. Between occupations, tripod must be removed and reset.

Footnote: Not applicable.

Discussion: The specification requires the tripod (or similar device) to be removed and reset over the mark between occupations. This specification reduces the possibility of any errors in measuring height of instrument and centering over mark.

Example: Not applicable.

6. Two or more occupations on all stations (reference - azimuth stations or eccentric stations).

Footnote: n: Two or more occupations on all stations (reference - azimuth stations or eccentric stations) is not required when there are two independent vectors at each station with one vector observed between reference-azimuth stations.

Discussion: The specification requires two (2) or more occupations on all reference to azimuth stations or eccentric stations established. This requirement is waived if two or more independent vectors are at each station with one vector observed between reference-azimuth stations.

Example: Not applicable.

7. At least two independent vectors required for each station.

Footnote: Not applicable.

Discussion: The specification requires at least two (2) independent vectors connected to each station. This requirement will not allow "radial" type surveys to be performed.

Example: Not applicable.

Specification: 9. Repeat Baselines.

1. Approximate equal number in N-S and E-W directions, minimum not less than (percent of independent baselines).

Footnote: o: An equal number of the repeat baselines must be distributed in the cardinal directions (north-south and east-west). In addition to the aforementioned requirements, it is required that the repeat baselines be evenly distributed throughout the project area. For rapid/fast static or kinematic positioning techniques the requirement is 5%.

Discussion: To be completed at a later date.

Example: To be completed at a later date.

2. Repeat baseline measurements for station pairs (reference-azimuth stations or eccentric stations).

Footnote: n: Two or more occupations on all stations (reference - azimuth stations or eccentric stations) is not required when there are two independent vectors at each station with one vector observed between reference-azimuth stations.

Discussion: To be completed at a later date.

Example: To be completed at a later date.

Specification: 10. Antenna Set-up.

1. Number of antenna phase center height measurements per session, not less than.

Footnote: p: The required number of measurements shall be two (2); one set of measurements at the beginning and one set of measurements at the end of each occupation. A set shall include one measurement in Metric and one measurement in English. If a Constant Height GPS Pole is used the user shall check the levels at the beginning, middle, and end of the observing session.

Discussion: This specification will minimize the blunders resulting from improper height of instrument measurements.

Example: Not applicable.

2. Tribrachs and/or other centering devices shall be checked and adjusted.

Footnote: q: Tribrachs and/or other centering devices shall be checked and adjusted (if necessary) at least every day of observation for Order B surveys. In lieu of this calibration, a Constant Height GPS Pole can be used and shall be calibrated if all three (3) bubbles are not centered.

r: Tribrachs and/or other centering devices shall be checked and adjusted (if necessary) at the beginning and the end of the project. In lieu of this calibration, a Constant Height GPS Pole can be used and shall be calibrated if all three (3) bubbles are not centered.

Discussion: To be completed at a later date.

Example: Not applicable.

3. Height of Instrument (HI) in metric and English.

Footnote: s: Antenna phase center shall be measured from station mark in meters (to mm) and feet (to hundredths of ft) or inches (to tenths of in). HI shall be measured and indicated on log sheet as either slant or vertical distance. This requirement is waived if a Constant Height GPS Pole is used. If a fixed height tripod pole is used the following information must be recorded:

- Vertical height of antenna (pole height plus antenna phase center).
- Pole height.
- Phase center offset.
- Fixed height pole (tripod) manufacturer.

Discussion: To be completed at a later date.

Example: Not applicable.

4. Independent plumb bob check required.

Footnote: t: Independent check of tribrachs and/or other centering devices shall be performed before, during, and after each mark observation session using a heavy weight plumb bob.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: 11. Photograph and Pencil Rubbing Required.

Footnote: u: A photograph and pencil rubbing is only required when the monument is either in bedrock; or an approved concrete pedestal; or an approved 3-D drivable. The photograph shall illustrate the tripod in position over the mark and vehicle location (if used) during the observation period.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: 12. Meteorological Observations Required.

Footnote: v: Meteorological data gathered at each mark observation shall meet the following:

- Weather data (pressure, relative humidity and temperature) for each session shall be recorded at the beginning and at the end of each GPS session.
- Temperature shall be measured and recorded to the nearest ± 1 Centigrade (°C).
- Pressure shall measured and recorded to the nearest ± 1 millibar (mb).
- Relative humidity shall recorded to the nearest ± 5 percent (%). Relative humidity can be measured or obtained from another source for that specific day and general location of the GPS observation session.
- Note weather conditions (i.e. wind, clouds, rain, snow, etc.) and rate of occurrence (e.g. 15 mph, partly cloudy, light, heavy, etc.) respectively, if present during the GPS observation session.
- Note any unusual weather conditions (i.e. passing thunderstorms, lightning, etc.).

w: Visual recording of weather data during observation session.

Discussion: Visual recording of weather data could include the following: approximate temperature, wind conditions, visual observation (i.e. partly cloudy), precipitation conditions (i.e. rain), and storm activity. This information will assist the data processor in determining if weather had any effect on the resolution of the baseline processing.

Example: Not applicable.

Specification: 13. Field Data Logs Required.

Footnote: y: Field data logs shall be maintained with, but not necessarily limited to, the following information for each master station occupation (see Attachment ***):

- Date.
- Station name.
- Session number.
- Start time and end time (UTC).
- Receiver and antenna make, model and serial numbers.
- Operator's name.

- Height of instrument as per these specifications.
- Meteorological measurements as per these specifications.
- Receiver calculated latitude, longitude and ellipsoidal height; satellites being tracked and their respective health status; and PDOP at the beginning and end of each GPS observation session.
- Note any unusual data while monitoring the receiver.

z: Field data logs shall be maintained with, but not necessarily limited to, the following information for each master station occupation (see Attachment ***):

- Date.
- Station name.
- Session number.
- Start time and end time (UTC).
- Receiver and antenna make, model and serial numbers.
- Operator's name.
- Height of instrument as per these specifications.
- Meteorological data as per these specifications.
- Note any unusual data while monitoring the receiver.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: 14. Maximum Elevation Angle (degrees) Between Operator and/or Vehicle and Antenna.

Footnote: Not applicable.

Discussion: The specification requires a maximum elevation of 5 degrees between operator and/or vehicle and the receiver's antenna to minimize signal blockage and multipath.

Example: Not applicable.

6.2. Data Analysis Specifications

Prior to performing a minimally constrained and constrained adjustment the network or traverse should be analyzed for possible outliers using loop closures, analysis of repeat baselines, and comparison of known and observed baselines. To facilitate in detecting the source of the blunder (height of instrument, centering errors, etc.), vectors should be displayed in northing, easting, upping (ΔN, ΔE, ΔU) or azimuth, distance and height ($\Delta\alpha$, Δs, Δh) or geodetic latitude, longitude, and height ($\Delta\phi$, $\Delta\lambda$, Δh).

Table 3 outlines the requirements for the post-processing, analyzing, and adjusting of GPS observational data relative to the HARN.

Table 3 - GPS Relative Positioning Data Analysis Specifications							
Specifications	**B Order**			**First Order**	**Second Order**		**Third Order**
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
1. Precise Ephemerides	Y	OP	OP	OP	NR		
2. Processing Requirements	MG[a]	MG[a]	MG[a]	MG[a]	MG[a]		
3. Loop Closure Requirements 1. Baselines from independent observing sessions, not less than	2[b]	2[b]	2[b]	2[b]	DES[o]		
2. Loop length, not to exceed (km)	400	100	50	50	DES[o]		
3. Loop length, minimum (km)	340	85	42	34	DES[o]		
4. Number of loop closures required per project	2[c]	2[c]	2[c]	2[c]	DES[o]		
5. Maximum misclosure for any single loop (ppm)	0.5[d]	1.0[d]	2.0[d]	5.0[d]	DES[o]		
6. Maximum average project loop misclosure (ppm)	0.3[d]	0.7[d]	1.3[d]	3.3[d]	DES[o]		
7. Maximum misclosure in any component, not to exceed (m)	.10	.10	.10	.10	DES[o]		
4. Baseline Closures 1. Differences between repeat unadjusted baselines computed and compared	Y[e]	Y[e]	Y[e]	Y[e]	Y[e]		
2. Differences between known and observed baselines computed and compared	Y[f]	Y[f]	Y[f]	Y[f]	Y[f]		
5. Relative Line Accuracy	F[g]	F[g]	F[g]	F[g]	F[g]		

Table 3 - GPS Relative Positioning Data Analysis Specifications							
Specifications	**B Order**			**First Order**	**Second Order**		**Third Order**
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
6. Blunder Detection Scheme	Y[h]	Y[h]	Y[h]	Y[h]	Y[h]		
7. Three Dimensional Adjustment	Y	Y	Y	Y	Y		
8. Absolute Residual in Minimally Constrained Adjustment	F[i]	F[i]	F[i]	F[i]	F[i]		
9. Control Position Closures	Y[j]	Y[j]	Y[j]	Y[j]	Y[j]		
10. Minimally Constrained Adjustment	Y[k]	Y[k]	Y[k]	Y[k]	Y[k]		
11. Constrained Adjustment	Y[l]	Y[l]	Y[l]	Y[l]	Y[l]		
12. Scalar (Covariance Matrix)	Y[m]	Y[m]	Y[m]	Y[m]	Y[m]		
13. Scale and Rotation (Control)	N	N	N	N	N[n]		

6.2.1. Table 3 - Legend

Y: Yes (required)
N: No (not required)
DES: Desirable
MG: Manufacturers Guidelines
F: Formula
m: meters
km: kilometers
ppm: parts per million

6.2.1. Explanation of Table 3 (Specifications, Footnotes, Discussion and Examples)

Specification: *1. Precise Ephemerides.*

Footnote: Not applicable.

Discussion: The precise ephemerides shall be used for A and B Order surveys and is optional for B Order, Class I and II and First Order surveys.

Example: Not applicable.

Specification: *2. Processing Requirements.*

Footnote: a: The consultant or agent of the State must present evidence that the guidelines published from the manufacturer provide adequate results. This evidence can be data from previous surveys or testing agencies such as the FGCS.

The consultant or agent of the State shall follow the guidelines published from the manufacturer in processing the observational data. ***Only non-trivial (independent) baselines shall be processed.*** Observation session shall be repeated if the percent of unacceptable baselines processed does not exceed 33 percent of the total number of baselines possible for each session.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *3. Loop Closure Requirements.*

1. Baselines from independent observing sessions, not less than

Footnote: b: Computational loops shall be composed of those baselines that close upon themselves in the shortest distance possible.

o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

2. Loop length, not to exceed (km)

Footnote: o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

3. Loop length, minimum (km)

Footnote: o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

4. Number of loop closures required per project

Footnote: c: At least two (2) loop closures for each survey project shall be performed to give a representative sample of the observations and data reductions performed. This requirement (of two loops) is waived if there are not enough stations to compute two loops. Loop closures shall be performed on those stations where the relative accuracy of the survey is questionable.

o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

5. Maximum misclosure for any single loop (ppm)

Footnote: d: The maximum misclosure for any loop and average misclosure for all loop closures performed for the project shall be computed as the sum of the squares of the misclosures in terms of loop length.

o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

6. Maximum average project loop misclosure (ppm)

Footnote: d: The maximum misclosure for any loop and average misclosure for all loop closures performed for the project shall be computed as the sum of the squares of the misclosures in terms of loop length.

o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

7. Maximum misclosure in any component, not to exceed (m)

Footnote: o: The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: 4. Baseline Closures.

1. Differences between repeat unadjusted baselines computed and compared

Footnote: e: Repeat baseline closures should be computed for each repeat baseline combination. The absolute value of the difference in each baseline component and the distance dependent error (part per million) are analyzed to determine if blunders exist. The difference in each vector component is compared to the rejection threshold (RT). The RT includes a base error and length dependent error that corresponds to the survey classification. In addition, the results of the repeat baseline measurements should be compared to the instrument specifications stated by the manufacturer.

$$RT_{ppm} = \frac{\sqrt{(e)^2 + (SC_{ppm} * d * 10^{-6})^2}}{d} * 10^6$$

e = Base error is 0.008 m for B Order and 0.010 m for First, Second, and Third Order.
SC_{ppm} = Survey Classification (i.e. B, First, Second, or Third Order).
d = Baseline distance in meters (m).

If the baseline component differences exceed the RT the baseline should be analyzed for possible blunders.

Discussion: This specification assists the user in identifying possible baseline outliers prior to an adjustment. Poor satellite geometry, insufficient occupation times, height of instrument and centering errors are possible sources that may cause outliers.

Example: As an example, a repeat baseline 804.674 m in length is surveyed at 20 ppm and has the following baseline component differences:

ΔX = -0.021 m
ΔY = -0.009 m
ΔZ = +0.011 m

The Rejection Threshold is as follows:

$$RT_{ppm} = \frac{\sqrt{(0.010)^2 + (20 * 804.674 * 10^{-6})^2}}{804.674} * 10^6 = 23.55\ ppm$$

The residual component differences in ppm is as follows:

$\Delta X = -0.021$ m or $|\{(-0.021) \div (804.674)\} * 10^6| = 26.1$ ppm
$\Delta Y = -0.009$ m or $|\{(-0.009) \div (804.674)\} * 10^6| = 11.2$ ppm
$\Delta Z = +0.011$ m or $|\{(+0.011) \div (804.674)\} * 10^6| = 13.7$ ppm

Therefore:

$\Delta X = 26.1$ ppm > 23.6 ppm.....fails (possible blunder)
$\Delta Y = 11.2$ ppm < 23.6 ppm.....passes
$\Delta Z = 13.7$ ppm < 23.6 ppm.....passes

2. Differences between known and observed baselines computed and compared

Footnote: f: Similar to the repeat baseline closures, known minus observed baseline closures provide insight on the location and possible cause of outliers. The differences between the known vector and observed vector components are compared to the same rejection threshold presented for repeat baseline closures.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *5. Relative Positioning Accuracy.*

Footnote: g: Relative Line Accuracy (RLA) (2σ) is computed by dividing the semi major axis (a) of the relative error ellipse by the spatial distance between the point (D). The RLA estimate can only be computed from performing a least squares adjustment or comparative estimation algorithm (Kalman filtering). A RLA must be computed and comply for all observed baselines.

Relative Line Accuracy

$$RLA_{ppm} = a/D_{AB}\,(10^6)$$

Symbol Definition

RLA_{ppm} = Relative Line Accuracy
a = Semi major axis of the relative error ellipse
D_{AB} = Distance between stations "A" and "B"

In order to satisfy the accuracy Standards outlined in Table 1, the line accuracy estimate for all lines must comply with the line accuracy listed in Table 1.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *6. Blunder Detection Scheme.*

Footnote: h: The adjustment software must perform the global variance test (Chi Square) and utilize a blunder detection scheme (i.e. Tau test) that tests the standardized (normalized) residuals. The global variance test and blunder detection scheme must be evaluated at a probability of 0.95 (95%).

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *7. Three Dimensional Adjustment.*

Footnote: Not applicable.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *8. Absolute Residual in a Minimally Constrained Adjustment.*

Footnote: i: The absolute value of the residual (v_o) and normalized residual (v_o/σ_v) for each vector component are analyzed for possible outliers. The absolute value of the residual ($|v_o|$) for each baseline component is compared to a defined threshold (v_c). The threshold equals an offset plus a length dependent error. The offset accounts for centering errors. The residual test provides the user a guideline of possible outliers.

Residual Test

$$v_c = \sqrt{(e)^2 + (SO_{ppm} * d * 10^{-6})^2}$$

SO_{ppm} = The lowest station order within the pair.
e = Base error is 0.010 m.
d = Baseline distance in meters (m).

Rejection Threshold

$$|v_o| \geq v_c$$

If the absolute residual computed in the minimally constrained adjustment (v_o) exceeds the threshold residual (v_c) the observation should be inspected for possible blunders and resolved.

In addition to the residual test, it is recommended that the normalized residuals be inspected for possible blunders using a blunder detection scheme (i.e. Tau Test).

Discussion: To be completed at a later date.

Example: As an example, a baseline 1340.560 m in length is surveyed between 4 ppm and 20 ppm stations and has the following residuals:

$v_x = +0.003$ m
$v_y = -0.031$ m
$v_z = +0.017$ m

The Residual Threshold is as follows:

$$v_c = \sqrt{(0.010)^2 + (20 * 1340.560 * 10^{-6})^2} = 0.029\,m$$

Therefore:

$v_x = |+0.003 \text{ m}| < 0.029$.....passes
$v_y = |-0.031 \text{ m}| \geq 0.029$.....fails (possible outlier)
$v_z = |+0.017 \text{ m}| < 0.029$.....passes

Specification: *9. Control Position Closures.*

Footnote: j: The Position Closure is computed by performing a minimally constrained adjustment and comparing the remaining known stations to their published values. A minimally (free) constrained adjustment consists of fixing the known latitude, longitude, and height of one station in the adjustment. Position Closure Estimates (PCE_{ppm}) provide the user an estimate of the quality of their known control. However, the user must realize that a "poor" PCE may also indicate an error in the GPS observations. Therefore, it is imperative that both the PCE and the Relative Line Accuracy (RLA) estimates are utilized to determine the quality of the survey. . A guideline for position closures was adopted to determine the integrity of the known survey control. The PCE includes a base error and the published Station Classification (SC_{ppm}).

Position Closure Estimate

$$PCE_{ppm} = \frac{\sqrt{(e)^2 + (SC_{ppm} * d * 10^{-6})^2}}{d} * 10^6$$

SC_{ppm} = Station Classification.
e = Base error is 0.010 m.
d = Distance between known stations in meters (m).

The PCE_{ppm} is compared to the computed Positional Errors (PE_{ppm}) for each known station in the minimally constrained adjustment.

Position Error***

$$PE_{ppm} = \frac{\sqrt{(\Delta\phi)^2 + (\Delta\lambda)^2 + (\Delta h)^2}}{d} * 10^6$$

$$\Delta\phi\,(m) = \frac{(a * (1 - e^2))}{\sqrt{(1 - e^2 * \sin^2\phi_m)^3}} * (\phi_c - \phi_p)_{rads} \quad (Rapp, 1984)$$

$$\Delta\lambda\,(m) = \frac{a * \cos\phi_m}{\sqrt{1 - e^2 * \sin^2\phi_m}} * (\lambda_c - \lambda_p)_{rads} \quad (Rapp, 1984)$$

d = Distance between known stations in meters (m).
Δh (m) = $h_c - h_p$
h_c = Computed ellipsoid height in meters (m).
h_p = Published ellipsoid height in meters (m).
a = Semi-major axis of the reference ellipsoid in meters (m).
e^2 = Square of the eccentricity of the reference ellipsoid in meters (m).
ϕ_c = Computed latitude for the minimally constrained adjustment in rads.
ϕ_p = Published latitude in rads.
λ_c = Computed longitude for the minimally constrained adjustment in rads.
λ_p = Published longitude in rads.

$$\phi_m = \text{Mean latitude: } \frac{(\phi_c + \phi_p)}{2} \text{ (degrees)}$$

Rejection Criteria

If the PE exceeds the PCE, the integrity of the known control should be verified and the results from the loop closures, repeat baseline analysis, known minus computed baselines, and residual test should be inspected for possible blunders.

$$PE_{ppm} \geq PCE_{ppm}$$

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *10. Minimally Constrained Adjustment.*

Footnote: k: Two (2) minimally constrained adjustments shall be performed which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data". One adjustment shall be unscaled and the other scaled (scalar applied).

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *11. Constrained Adjustment.*

Footnote: l: A constrained scaled adjustment shall be supplied which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data".

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *12. Scalar (Covariance Matrix).*

Footnote: m: Immediately following the blunder detection of the minimally constrained adjustment, a scalar is applied to reflect proper weighting and to evaluate the adequacy of the variance of unit weight. The estimated variance factor sought for each adjustment is a value close to unity with no flagged residuals. Obtaining a scalar can be an iterative process with selection of initial scalar values influenced by prior experience with the manufacturer's equipment and software.

Discussion: To be completed at a later date.

Example: Not applicable.

Specification: *13. Scale and Rotation (Control).*

Footnote: n: Scale and rotation may be required when establishing control relative to the North American Datum of 1927 (NAD 27) or on the North American Datum of 1983 (1991) if existing control does not fit with processed GPS vectors. The entity performing the adjustments shall contact the agency for instructions before scale and rotation is applied.

Discussion: To be completed at a later date.

Example: Not applicable.

6.3. Data Submittal Specifications

The submittal section was developed for those agencies that use contractual assistance to obtain surveying services (WIDOT, 1992).

Table 4 - GPS Relative Positioning Data Submittal Specifications

Specifications	B Order			First Order	Second Order		Third Order
	Class I	Class II	Class III		Class I	Class II	
Geometric Relative Accuracy Standard	1 ppm	2 ppm	4 ppm	10 ppm	20 ppm	50 ppm	100 ppm
1. Project Report	Y[a]	Y[a]	Y[a]	Y[a]	Y[a]	Y[a]	Y[a]
2. Project Diagram	Y[b]	Y[b]	Y[b]	Y[b]	Y[b]	Y[b]	Y[b]
3. Project Instructions or Contract Specifications	Y[c]	Y[c]	Y[c]	Y[c]	Y[c]	Y[c]	Y[c]
4. Final Station Coordinate List	Y[d]	Y[d]	Y[d]	Y[d]	Y[d]	Y[d]	Y[d]
5. Session Observing Schedules	Y[e]	Y[e]	Y[e]	Y[e]	Y[e]	Y[e]	Y[e]
6. Loop Closures	Y[f]	Y[f]	Y[f]	Y[f]	DES[f]	DES[f]	DES[f]
7. Baseline Closures	Y[g]	Y[g]	Y[g]	Y[g]	Y[g]	Y[g]	Y[g]
8. Control Position Closures	Y[h]	Y[h]	Y[h]	Y[h]	Y[h]	Y[h]	Y[h]
9. Minimally Constrained Adjustment	Y[i]	Y[i]	Y[i]	Y[i]	Y[i]	Y[i]	Y[i]
10. Constrained Adjustment	Y[j]	Y[j]	Y[j]	Y[j]	Y[j]	Y[j]	Y[j]
11. Baselines Removed From Adjustments	Y[k]	Y[k]	Y[k]	Y[k]	Y[k]	Y[k]	Y[k]
12. Observation Logs	Y[l]	Y[l]	Y[l]	Y[l]	Y[l]	Y[l]	Y[l]
13. Photographs and/or Pencil Rubbings	Y[m]	Y[m]	Y[m]	Y[m]	OP[m]	OP[m]	OP[m]
14. Raw Phase Observational Data (R-files)	Y/OP[n]	Y/OP[n]	Y/OP[n]	Y/OP[n]	OP[n]	OP[n]	OP[n]
15. Baseline Vectors (G-file)	Y/OP[o]	Y/OP[o]	Y/OP[o]	Y/OP[o]	OP[o]	OP[o]	OP[o]
16. Project and Station Occupation (B-file)	Y/OP[p]	Y/OP[p]	Y/OP[p]	Y/OP[p]	OP[p]	OP[p]	OP[p]
17. Descriptions or Recovery Notes (D-file)	Y[q]	Y[q]	Y[q]	Y/OP[q]	OP[q]	OP[q]	OP[q]

6.3.1. Table 4 - Legend

Y:	Yes (required)
N:	No (not required)
OP:	Optional
DES:	Desirable
ppm:	parts per million

6.3.2. Explanation of Table 4 (Specifications, Footnotes, Discussion and Examples)

Specification: *1. Project Report.*

Footnote: a: A project report shall be supplied in a binder and shall include all of the Submittal Items in the order listed under Table 4. The report shall address the entire project and shall include all of the specified Submittal Items under Table 4 and include, but not necessarily be limited to, the following:

1. Introduction. The Introduction shall include, but not necessarily be limited to, the following:
   - The number and type of stations/marks established.
   - The accuracy standards of the project.
   - Timeframe of project (i.e. arrival and departure dates of field survey and start and ending dates of data processing, adjustment and analysis).
   - Location of project.
   - The name, mailing address and phone number of the point of contact for which the survey was performed and for the organization that performed the services.
2. Personnel. Personnel involved in the data acquisition; data processing, data adjustment and data analysis; and project report shall be supplied.
3. Instrumentation. Describe the make, model and serial number of each receiver used on the project.
4. Software. Describe the software used to post-process, analyze and adjust the GPS observational data for this project.
5. Project Diagram. A project diagram (sketch) shall be supplied and can be referred to as an Attachment.
6. Project Instructions or Contract Specifications. Project instructions or contract specifications shall be supplied and can be referred to as an Attachment.
7. Horizontal Control Stations. A description of the horizontal control stations used for the project shall be supplied.
8. Vertical Control Stations. A description of the vertical control stations used for the project shall be supplied.
9. Final Station Coordinate List. A final station coordinate listing shall be shall be supplied and can be referred to as an Attachment. A

brief description on the content of the data shall be supplied in the report.

10. Session Observing Schedules. A narrative discussing any field acquisition problems shall be supplied in the report. Session observing schedules shall be supplied and can be referred to as an Attachment.
11. Data Processing Results. A narrative discussing the results of the processed observational data shall be supplied.
12. Loop Closures. A narrative discussing the results of loop closures shall be supplied in the report. Loop closures shall be supplied and can be referred to as an Attachment.
13. Baseline Closures. A narrative discussing the results of baseline closures shall be supplied in the report. Baseline closures shall be supplied and can be referred to as an Attachment.
14. Control Position Closures. A narrative discussing the results of control position closures shall be supplied in the report. Control position closures shall be supplied and can be referred to as an Attachment.
15. Minimally Constrained Adjustment. A narrative discussing the results of the minimally constrained adjustments shall be supplied in the report. Minimally constrained adjustments shall be supplied and can be referred to as an Attachment.
16. Constrained Adjustment. A narrative discussing the results of the constrained adjustments shall be supplied in the report. Constrained adjustments shall be supplied and can be referred to as an Attachment.
17. Baselines Removed From Adjustments. The listing of baselines removed from the adjustments and the reasoning used shall be supplied.
18. Observation Logs. Observation logs shall be supplied as an Attachment.
19. Photographs and/or Pencil Rubbings. Photographs and/or pencil rubbings shall be supplied as an Attachment.
20. Raw Phase Observational Data (R-files).
21. Baseline Vectors (G-file).
22. Project and Station Occupation Data (B-file).
23. Descriptions or Recovery Notes (D-file).

Specification: *2. Project Diagram.*

Footnote: b: A project diagram (sketch) shall be supplied which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data". The diagram shall depict non-trivial (independent) baselines observed and the final baseline vectors used. The observed baselines shall be delineated by solid lines and the baselines removed (or not used) in the final constrained adjustment shall delineated by dashed lines.

Specification: *3. Project Instructions or Contract Specifications.*

Footnote: c: Project instructions or contract specifications shall be supplied and can be referred to as an Attachment.

Specification: *4. Final Station Coordinate List.*

Footnote: d: A final adjusted coordinate list shall be supplied which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data". In addition, the final adjusted coordinate list shall include following: station name; geodetic coordinates in latitude, longitude and ellipsoidal height; state plane coordinates in X and Y in both meters and feet (using the U.S. Survey Foot); and the appropriate standard errors for each dimension of position in meters based on the appropriate NAD 83 (1991) state plane zone (as defined by NGS publication) on hard copy as well as in ASCII format MS/DOS formatted 3 1/2" HD discs or CD ROM.

Specification: *5. Session Observing Schedules.*

Footnote: e: A narrative discussing any field acquisition problems shall be supplied in the report. Session observing schedules shall be supplied and can be referred to as an Attachment.

Specification: *6. Loop Closures.*

Footnote: f: A table indicating the loop closures shall be supplied. The table shall include the following: stations forming the loop; calculated misclosure (in meters); length of loop (in meters); required and calculated misclosure (in ppm); and vector information (i.e. session and day). A report discussing if the loop closures satisfied the specifications or not shall be supplied.

The specification is desirable for Second and Third Order surveys only if the user cannot automatically (through software routine) calculate the loop closures.

Specification: *7. Baseline Closures.*

Footnote: g: A table indicating the comparisons of the differences (ΔX, ΔY and ΔZ) between known and observed, and repeat unadjusted baselines shall be supplied. The table shall include the following: station to and from; vector components (ΔX, ΔY and ΔZ); distance between stations (in meters); required and calculated accuracy (Rejection Threshold - RT) in ppm; observation day and session time (UTC). A report discussing if the comparisons satisfied the specifications or not shall be supplied.

Specification: *8. Control Position Closures.*

Footnote: h: A table illustrating the position closures between computed coordinates and published/recently computed coordinates shall be supplied. The table shall include the following: station to and from; vector components ($\Delta\phi$, $\Delta\lambda$ and Δh) (in meters); distance between stations (in meters); Position Closure Estimate (PCE) and Positional Error (PE) (in ppm); and pass or fail indication.

A report discussing if the position closures satisfied the specifications or not shall be supplied.

Specification: *9. Minimally Constrained Adjustments.*

Footnote: i: Two (2) minimally constrained adjustments shall be supplied which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data". One adjustment shall be unscaled and the other scaled. In addition, the minimally constrained adjustments shall include the following: input and output least squares adjustment files (in ASCII format on hard copy, MS/DOS formatted 3 1/2" HD disks and CD ROM) shall be supplied.

The scalar value (to modify the GPS error estimates) shall be noted on the scaled adjustments.

The report shall indicate if the absolute residuals in the minimally constrained adjustment were satisfied or not.

Specification: *10. Constrained Adjustment.*

Footnote: j: A constrained scaled adjustment shall be supplied which follows the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data". In addition, the constrained scaled adjustment shall include the following: input and output least squares adjustment files (in ASCII format on hard copy, MS/DOS formatted 3 1/2" HD disks and CD ROM) shall be supplied. The scalar value (to modify the GPS error estimates) shall be noted on the scaled adjustment.

Specification: *11. Baselines Removed From Adjustments.*

Footnote: k: A report shall indicate those baselines removed from the adjustments that are outliers or blunders and the justification or reasoning used shall be supplied.

Specification: *12. Observation Logs.*

Footnote: l: Observation logs shall be supplied as an Attachment.

Specification: *13. Photographs and/or Pencil Rubbings.*

Footnote: m: Photographs and/or pencil rubbings shall be supplied as an Attachment.

The specification is optional for Second and Third Order surveys if the user so desires.

Specification: *14. Raw Phase Observational Data (R-files).*

Footnote: n: The raw phase observational data shall be supplied and follow the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data" if the user chooses to submit the project to NGS otherwise, the specification is optional. At a minimum all raw GPS observational data from this project shall be made readily available to the client upon request from the entity that performs the GPS services if the client so desires this data. The client will retain ownership of this data. If the entity that performs the GPS services decides to no longer retain the data, the entity will supply the data to the client on the most efficient media available and agreeable with the client.

Specification: *15. Baseline Vectors (G-file).*

Footnote: o: The baseline vectors shall be supplied and follow the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data" if the user chooses to submit the project to NGS otherwise, all baseline vector solution files shall be supplied in ASCII format on MS/DOS formatted 3 1/2" HD disks or CD ROM.

Specification: *16. Project and Station Occupation Data (B-file).*

Footnote: p: The project and station occupation data shall be supplied and follow the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data" if the user chooses to submit the project to NGS otherwise, the specification is optional.

Specification: 17. Descriptions or Recovery Notes (D-file).

Footnote: q: The descriptions or recovery notes shall be supplied and follow the recommended procedures under NOAA, "Input Formats and Specifications of the National Geodetic Survey Data Base, ANNEX L - Guidelines for Submitting GPS Relative Positioning Data".

The specification is optional for First (i.e. non-densification control, azimuth marks), Second and Third Order surveys.

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SECOND APPENDIX TO AERO-METRIC, INC. REPORT
FEDERAL VERTICAL SURVEY CONTROL SPECIFICATIONS

2.2 Vertical Control Network Standards

When a vertical control point is classified with a particular order and class, NGS certifies that the orthometric elevation at that point bears a relation of specific accuracy to the elevations of all other points in the vertical control network. That relation is expressed as an elevation difference accuracy, b. An elevation difference accuracy is the relative elevation error between a pair of control points that is scaled by the square root of their horizontal separation traced along exiting level routes.

Table 2.2—Elevation accuracy standards

Classification	*Maximum elevation difference accuracy*
First-order, class I	0.5
First-order, class II	0.7
Second-order, class I	1.0
Second-order, class II	1.3
Third-order	2.0

An elevation difference accuracy, b, is computed from a minimally constrained, correctly weighted, least squares adjustment by

$$b = S/\sqrt{d}$$

where

d = approximate horizontal distance in kilometers between control point positions traced along existing level routes.

S = propagated standard deviation of elevation difference in millimeters between survey control points obtained from the least squares adjustment. Note that the units of b are (mm) / √ (km).

The elevation difference accuracy pertains to all pairs of points (but in practice is computed for a sample). The worst elevation difference accuracy (largest value) is taken as the provisional accuracy. If this is substantially larger or smaller than the intended accuracy, then the provisional accuracy takes precedence.

As a test for systematic errors, the variance factor ratio of the new survey is computed by the Iterated Almost Unbiased Estimator (IAUE) method described in appendix B. This computation combines the new survey measurements with existing network data, which are assumed to be correctly weighted and free of systematic error. If the variance factor ratio is substantially greater than unity, then the survey does not check with the network, and both the survey and the network data will be examined by NGS.

Computer simulations performed by NGS have shown that a variance factor ratio greater than 1.5 typically indicates systematic errors between the survey and the network. Setting a cutoff value higher than this could allow undetected systematic error to propagate into the national network. On the other hand, a higher cutoff value might be considered if the survey has only a small number of connections to the network, because this circumstance would tend to increase the variance factor ratio.

In some situations, a survey has been designed in which different sections provide different orders of control. For these multi-order surveys, the computed elevation difference accuracies should be grouped into sets appropriate to the different parts of the survey. Then, the largest value of b in each set is used to classify the control points of that portion, as discussed above. If there are sufficient connections to the network, several variance factor ratios, one for each section of the survey, should be computed.

3.5 Geodetic Leveling

Geodetic leveling is a measurement system comprised of elevation differences observed between nearby rods. Leveling is use to extend vertical control.

Network Geometry

Order *Class*	*First* *I*	*First* *II*	*Second* *I*	*Second* *II*	*Third*
Bench mark spacing not more than (km)	3	3	3	3	3
Average bench mark spacing not more than (km)	1.6	1.6	1.6	3.0	3.0
Line length between network control points not more than (km)	300	100	50	50 (double-run) 25 (single-run)	25 10

New surveys are required to tie to existing network bench marks at the beginning and end of the leveling line. These network bench marks must have an order (and class) equivalent to or better than the intended order (and class) of the new survey. First-order surveys are required to perform check connections to a minimum of six bench marks, three at each end. All other surveys require a minimum of four check connections, two at each end. “Check connection” means that the observed elevation difference agrees with the adjusted elevation difference within the tolerance limit of the new survey. Checking the elevation difference between two bench marks located on the same structure, or so close together that both may have been affected by the same localized disturbance, is not considered a proper check. In addition, the survey is required to connect to any network control points within 3 km of its path. However, if the survey is run parallel to existing control, then the following table specifies the maximum spacing of extra connections between the survey and the control. At least one extra connection should always be made.

Distance, survey to network	Maximum spacing of extra connections (km)
0.5 km or less	5
0.5 km to 2.0 km	10
2.0 km to 3.0 km	20

Instrumentation

Order Class	*First I*	*First II*	*Second I*	*Second II*	*Third*
Leveling instrument					
Minimum repeatability of line of sight	0.25”	0.25”	0.50”	0.50”	1.00”
Leveling rod construction	IDS	IDS	IDS† or ISS	ISS	Wood or Metal
Instrument and rod resolution (combined)					
Least count (mm)	0.1	0.1	0.5-1.0*	1.0	1.0

(IDS—Invar, double scale)
(ISS—Invar, single scale)
†if optional micrometer is used.
*1.0 mm if 3-wire method, 0.5 mm if optical micrometer.

Only a compensator or tilting leveling instrument with an optical micrometer should be used for first-order leveling. Leveling rods should be one piece. Wooden or metal rods may be employed only for third-order work. A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate (“turtle”) weighing at 7kg should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with a double-headed nail should be driven to a firm depth.

Calibration Procedures

Order Class	*First I*	*First II*	*Second I*	*Second II*	*Third*
Leveling instrument					
Maximum collimation error, single line of sight (mm/m)	0.05	0.05	0.05	0.05	0.10
Maximum collimation error, reversible compensator type instruments, mean of two lines of sight (mm/m)	0.02	0.02	0.02	0.02	0.04
Time interval between collimation error determinations not longer than (days)					
Reversible compensator	7	7	7	7	7
Other types	1	1	1	1	7
Maximum angular difference between two lines of sight, reversible compensator	40″	40″	40″	40″	60″
Leveling rod					
Minimum scale calibration standard	N	N	N	M	M
Time interval between scale calibrations (yr)	1	1	—	—	—
Leveling rod bubble verticality maintained to within	10′	10′	10′	10′	10′

(N—National standard)
(M—Manufacturer’s standard)

Compensator-type instruments should be checked for proper operation at least every 2 weeks of use. Rod calibration should be repeated whenever the rod is dropped or damaged in any way. Rod levels should be checked for proper alignment once a week. The manufacturer’s calibration standard should, as a minimum, describe scale behavior with respect to temperature.

Field Procedures

Order Class	*First I*	*First II*	*Second I*	*Second II*	*Third*
Minimal observation method	micro-meter	micro-meter	micro-meter or 3-wire	3-wire	center wire
Section running	SRDS or DR or SP	SRDS or DR or SP	SRDS or DR† or SP	SRDS or DR*	SRDS or DR§
Difference of forward and backward sight lengths never to exceed					
per setup (m)	2	5	5	10	10
per section (m)	4	10	10	10	10
Maximum sight length(m)	50	60	60	70	90
Minimum ground clearance of line of sight (m)	0.5	0.5	0.5	0.5	0.5

Field Procedures—Continued

Order Class	*First I*	*First II*	*Second I*	*Second II*	*Third*
Even number of setups when not using leveling rods with detailed calibration ...	yes	yes	yes	yes	—
Determine temperature gradient for the vertical range of the line of sight at each setup	yes	yes	yes	—	—
Maximum section misclosure (mm)	3√D	4√D	6√D	8√D	12√D
Maximum loop misclosure (mm)	4√E	5√E	6√E	8√E	12√E
Single-run methods					
Reverse direction of single runs every half day............	yes	yes	yes	—	—
Nonreversible compensator leveling instruments					
Off-level/relevel instrument between observing the high and low rod scales.....	yes	yes	yes	—	—
3-wire method					
Reading check (difference between top and bottom intervals) for one setup not to exceed (tenths of rod units)...........................	—	—	2	2	3
Read rod 1 first in alternate setup method	—	—	yes	yes	yes
Double scale rods					
Low-high scale elevation difference for one setup not to exceed (mm)					
With reversible compensator...............	0.04	1.00	1.00	2.00	2.00
Other instrument types:					
Half-centimeter rods.......	0.25	0.30	0.60	0.70	1.30
Full-centimeter rods	0.30	0.30	0.60	0.70	1.30

(SRDS—Single-Run, Double Simultaneous procedure)
(DR—Double-Run)
(SP—Spur, less than 25 km, double-run)
D—shortest length of section (one-way) in km
E—perimeter of loop in km
† Must double-run when using 3-wire method.
* May single-run if line length between network control points is less than 25 km.
§ May single-run if line length between network control points is less than 10km.

Double-run leveling may always be used, but single-run leveling done with the double simultaneous procedure may be used only where it can be evaluated by loop closures. Rods should be leap-frogged between setups (alternate setup method. The date, beginning and ending times, cloud coverage, air temperature (to the nearest degree), temperature scale, and average wind speed should be recorded for each section plus any changes in the date, instrumentation, observer of time zone. The instrument need not be off-leveled/releveled between observing the high and low scales when using an instrument with a reversible compensator. The low-high scale difference tolerance for a reversible compensator is used only for the control of blunders.

With double scale rods, the following observing sequence should be used:

backsight, low-scale
backsight, stadia
foresight, low-scale
foresight, stadia
off-level/relevel or reverse compensator
foresight, high-scale
backsight, high-scale

Office Procedures

Order Class	*First I*	*First II*	*Second I*	*Second II*	*Third*
Section misclosures (backward and forward)					
Algebraic sum of all corrected section misclosures of a leveling line not to exceed (mm)....	3√D	4√D	6√D	8√D	12√D
Section misclosure not to exceed (mm)	3√E	4√E	6√E	8√E	12√E
Loop misclosures					
Algebraic sum of all corrected misclosures not exceed (mm)	4√F	5√F	6√F	8√F	12√F
Loop misclosure not to exceed (mm)	4√F	5√F	6√F	8√F	12√F

(D—shortest length of leveling line (one-way) in km)
(E—shortest one-way length of section in km)
(F—length of loop in km)

The normalized residuals from a minimally constrained least squares adjustment will be checked for blunders. The observation weights will be checked by inspecting the postadjustment estimate of the variance of unit weight. Elevation difference standard errors computed by error propagation in a correctly weighted least squares adjustment will indicate the provisional accuracy classification. A survey variance factor ratio will be computed to check for systematic error. The least squares adjustment will use models that account for:

gravity effect or orthometric correction
rod scale errors
rod (Invar) temperature
refraction—need latitude and longitude to 6″ or vertical temperature difference observations between 0.5 and 2.5 m above the ground
earth tides and magnetic field
collimation error
crustal motion

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Appendix B

MINUTES OF SEPTEMBER 25, 2012
SEWRPC TASK FORCE ON DATUM MIGRATION

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KWB/lgh
11/19/12
Minutes-Review Preliminary Draft TR No. 50. (00207333).DOC

MINUTES

MEETING OF THE TECHNICAL TASK FORCE CREATED BY SEWRPC TO REVIEW THE PRELIMINARY DRAFT OF SEWRPC TECHNICAL REPORT NO. 50

DATE:	September 25, 2012
TIME:	9:00 A.M.
PLACE:	Commissioners' Conference Room Regional Planning Commission Offices W239 N1812 Rockwood Drive Waukesha, Wisconsin

Members Present

Kurt W. Bauer, Chairman	Executive Director Emeritus, SEWRPC, County Surveyor Kenosha, Milwaukee, Walworth, and Waukesha Counties
Earl F. Burkholder	Consulting Geodetic Engineer
Robert W. Merry	Geomatics Manager, Aero-Metric, Inc.
Glen R. Schaefer	Geodetic Engineer, Wisconsin Department of Transportation
Jeffrey B. Stroub	Vice President, Aero-Metric, Inc.

Guests Present
None

SEWRPC Staff Present

Philip C. Evenson	Special Projects Advisor
Donald P. Simon	Chief Planning Illustrator, SEWRPC; Deputy County Surveyor for Kenosha, Milwaukee, Ozaukee, Walworth, and Waukesha Counties
Lynn G. Heis	Recording Secretary

CALL TO ORDER AND ROLL CALL

Chairman Bauer called the meeting to order at 9:00 A.M. Roll call was taken by circulating an attendance signature sheet, and a quorum was declared present.

INTRODUCTION

Chairman Bauer welcomed the Task Force members to the Commission offices; and, on behalf of the Commission, thanked the members for their willingness to serve on the Task Force, and to make their experience and knowledge available to the Commission as a public service.

CHARGE TO COMMITTEE

Chairman Bauer indicated that the Commission's charge to the Task Force was to conduct a critical review of the preliminary draft of SEWRPC Technical Report No. 50, *Cost Estimate for Resurvey of Regional Control Survey Network,* September 2012, and to recommend needed changes in the findings and recommendations set forth in the report.

PROPOSED PROCEDURE

Chairman Bauer indicated that the procedure proposed to be followed in the conduct of the Task Force work was to review on a page-by-page basis the preliminary draft of the report concerned. He noted that all members of the Task Force had been provided with a copy of the draft for review prior to the meeting. He noted that the report was intended to describe the scope and cost of the work required to replace the four foundational elements of any good parcel-based land information or public works management system:

1. A map projection and related datums;
2. A survey control network that manifests the projection and datums on the surface of the earth;
3. A large-scale topographic map of the area concerned; and
4. A matching large-scale cadastral map of the area concerned.

The replacement of these foundational elements would be required for any sound migration of the existing parcel-based land information and public works management systems being developed within the region from the legacy datums in use to one of the newer datums created and promulgated by the National Geodetic Survey. The existing land information and public works management systems, while under development, are operational and functioning well within the Region.

Chairman Bauer said that it was hoped that the Task Force could complete its work in a single meeting. The proceedings of that meeting would be set forth in the minutes. A copy of those minutes would then be provided to all Task Force members for review, and the Task Force members would be asked to indicate their approval or conditional approval of the minutes, or to request a second meeting to act on the minutes. The work of the Task Force would be concluded when the minutes of the meeting had been approved.

REVIEW OF PRELIMINARY DRAFT OF REPORT CONCERNED

The Task Force then undertook a page-by-page review of the preliminary draft of the report concerned, that draft being dated September 2012. The following comments were raised, discussed, and acted upon in the meeting.

Mr. Evenson suggested that the proposed type of Commission report be changed from a Technical Report to a Memorandum Report. He noted that the former type of report was intended to make available information assembled on a work progress basis by the Commission staff during the course of a planning program; the latter being intended to document the results of locally requested special studies. He also suggested that in order to reflect the full scope of the report its title be changed to: "*Estimate of the Costs of Converting the Foundational Elements of the Land Information and Public Works Management Systems in Southeastern Wisconsin from Legacy to New Datums*." Following a brief discussion, the suggested changes were approved by consensus.

Mr. Schaefer noted that he had provided to the Commission staff a number of editorial corrections which he understood had been made. One of these relates, he said, in identifying specific datums, to use of the full year—for example, 2007—in the notation, instead of the abbreviation 07; and that this manner of notation be used throughout the text. He also noted that the word "benchmark" was to be used throughout the text to two words, "bench mark." The suggested changes were approved by consensus.

Mr. Schaefer noted that the National Geodetic Survey (NGS) may have developed guidelines on standards and specifications for Global Positioning System (GPS) surveys based upon the Wisconsin Department of Transportation (WisDOT) guidelines appended to the draft report. If this was in fact the case, he suggested the report should append the NGS rather than the WisDOT document to the final report. Mr. Merry indicated that he did conduct a literature search in an attempt to find applicable GPS survey standards, and based upon that search concluded that the WisDOT guidelines were the best available.

Mr. Burkholder then referred to the last paragraph on page 1 of the report and asked why reference was made to the Clarke Spheroid of 1866. Chairman Bauer indicated he believed the reference was desirable since other spheroids—ellipsoids—were used for the newer datums, and this should be understood by all of the potential readers of the report, the great majority of whom would not be geodesists.

Mr. Schaefer referred to the third line of the first paragraph on page 1, indicating that the term "Geographic Reference System" should be changed to "Geodetic Reference System."

Mr. Burkholder referred to the second full paragraph on page 4, recommending that the last word of the first line of the last sentence be changed from "no" to "little."

Mr. Schaefer questioned the meaning and relevance of the second sentence of the second full paragraph on page 4, noting that if the sentence was construed as referring to NAD 83, the statement was incorrect since that datum was not related to military or navigational issues. If, however, the sentence was construed as referring to the use of WGS 84, it was correct. Chairman Bauer responded that in his opinion, NAD 83 would not have come into being if military needs had not required a change in the mapping spheroids and related datums originally used worldwide such as those based on the Clarke and Bessel, spheroids, among others. The development of NAD 83 was certainly not required to meet land surveying or civil engineering needs, the legacy 27 and 29 datums and related State Plane Coordinates and Mean Sea Level elevations being perfectly adequate for civil applications. Mr. Schaefer responded that the legacy horizontal and vertical datums were not integrated, that is, were not related to a single ellipsoid and, therefore, to be consistent with state-of-the-art geodetic practices would eventually have had to be replaced. Chairman Bauer indicated that the fact that the 27 horizontal datum was based upon the Clarke Spheroid and the 29 vertical datum was based upon Mean Sea Level and not to a spheroid, was a matter of indifference to practicing land surveyors and civil engineers. Massive civil engineering works, such as the transcontinental railway systems, the interstate highway system, the air navigation system, the U.S. Geological Survey quadrangle mapping program, the U.S. Coast and Geodetic Survey nautical and aeronautical charting programs, and such large local civil engineering projects as construction of the deep tunnel combined and sanitary sewer overflow abatement system in the Milwaukee area were all built utilizing the legacy datums. Upon further discussion it was the consensus to leave the paragraph as written.

Mr. Burkholder called attention to the second sentence of the third full paragraph on page 4 indicating that in his opinion the use of the phrase "patently absurd" seemed harsh. Chairman Bauer indicated that in his opinion the idea that the new datums would in some way result in more accurate maps was indeed absurd and this, in his opinion, should be said. He noted that accurate maps could be, and historically have been, prepared without reference to an identified projection or attendant datum. Mr. Schaefer observed that the use of a common datum and projection, while not needed to produce accurate maps, was needed to permit the areawide correlation of otherwise disparate maps and mapping related data. Upon discussion it was agreed that the following sentence should be added to the end of the third full paragraph on page 4:

> "Importantly, the use of a common datum and projection permits ready correlation of disparate surveying and mapping programs, minimizes the effort required for transformation of data from one datum to another, and reduces confusion in the use of both analog and digital spatial related data."

Chairman Bauer called attention to the second full paragraph on page 5 and suggested that the second and third sentences of the paragraph be revised to read as follows:

> "Adjustment of the NAD 83 and NAVD 88 datums have resulted in the creation of NAD 83 (1991), NAD 83 (2007), NAD 83 (2011), NAVD 88 (2007) and NAVD 88 (2012). NGS is presently in the process of creating NAD 83 (2022)."

After further discussion it was agreed that the following footnote should be added to page 5.

> The NGS does not regard the various versions of NAD 83 or NAVD 88 as "new datums." The "datum tag" used is considered by the NGS to identify differing "realizations"—that is, refinements or adjustments—of the datum concerned. From this viewpoint, the first new datum proposed to be introduced by the NGS since the introduction of NAD 83 datum would be the ITRF-17 datum. From the Commission standpoint, the various adjustments of the NAD 83 and NAVD 88 datums are, in effect, new datums since the coordinate position and orthometric height of a monumented survey station would have different values under each adjustment.

In answer to a question by Mr. Evenson, Mr. Schaefer replied that NAD 27 did not evolve into a similar series of adjustments as the NAD 83 datum because the 27 datum was not mathematically related to the earth's center of gravity as is the 83 datum. Mr. Burkholder noted that more precisely stated, the datum was not related to the earth's center of mass—the center of gravity being the center of mass only in a uniform gravity field; however, he said, the earth's gravity field is not uniform. Chairman Bauer indicated that while Mr. Schaefer provided a scientifically correct response to Mr. Evenson's question, another reason might be advanced, namely, that the 27 datum and the State Plane Coordinate Systems based upon it and the 29 vertical datum were perfectly adequate for land surveying and most civil engineering applications.

Mr. Burkholder, referring to the second full paragraph on page 5, indicated that it was his understanding that migration to the ITRF 17 datum would involve relatively small changes in position values. Mr. Merry disagreed, indicating that it was estimated that the shifts in horizontal position from NAD 83—not WGS 84—to the ITRF 17 might approximate, or exceed, 2.2 meters.

Both Mr. Schaefer and Mr. Merry indicated that to be technically consistent the penultimate sentence of the second paragraph should be revised by removing the reference in the sentence to WGS 84.

Mr. Burkholder and Mr. Merry referred to the last paragraph on page 5, questioning the use of the term "some" in referring to practicing surveyors and land information system managers questioning the continued use of the legacy datums within the region. Chairman Bauer indicated that, of course, it was not known how many practitioners have raised, or may raise, the question; but Commission staff experience in dealing with private sector land surveyors, public works engineers, and land information system managers clearly indicated that a relatively few in each category continued to raise the question, and that the majority of the practitioners concerned do not raise the question. After some discussion, it was agreed that the phrase "but not all" would be inserted in the text to clarify the use of the word "some."

Mr. Evenson referred to the last paragraph on page 5 and suggested that the second sentence of the paragraph identifying Mr. Donald G. Dittmar, as one land information system manager that has raised the issue of conversion from the legacy to the newer datums, be struck. Mr. Evenson indicated that it would be more politic to avoid identifying a specific individual in this case, as well as being consistent with historic Commission practice. Upon some discussion it was agreed to eliminate the initial phrase in the sentence referring to Mr. Dittmar and to revise the sentence to read:

> "Indeed the Commission convened an interagency staff meeting to address these questions."

Mr. Evenson in a related matter called attention to the first partial paragraph on page 6 and suggested that the last sentence of the paragraph be revised to also eliminate the reference to Mr. Dittmar, the sentence being reworded to read as follows:

> "It was, nevertheless, agreed that it would be helpful to those staffs for the Commission to develop an estimate of the probable costs entailed in the transformation of the existing control survey network and attendant foundational mapping elements to the NAD 83 (2007) and NAVD 88 (2007) datums."

For the same reason Mr. Evenson suggested that the first phrase of the first sentence of the first full paragraph on page 6 be struck, the phrase “in response to Mr. Dittmar’s request” being replaced with “accordingly.”

Mr. Schaefer called attention to the first line on page 7 indicating that the phrase “Geodetic Reference Spheroid of 1980” should be replaced by the phrase “Geodetic Reference System of 1980 (GRS 80).”

Mr. Schaefer also called attention to the second full sentence on page 7 which indicated that State Plane Coordinates on the new system were expressed in meters in order to avoid confusion with such coordinates on the original State Plane Coordinate System which are expressed in U.S. Survey Feet. He indicated the reason cited was questionable and that the phrase “in order to avoid confusion with State Plane” should be struck and replaced with the word “while”, and that the word “which” in the sentence also be struck. He indicated that it was his understanding that the use of meters as the unit of measurement in the new State Plane Coordinate System was proposed because the Federal government was at the time promoting the use of the metric system within the United States.

Mr. Schaefer also called attention to the last sentence of the first partial paragraph on page 7 indicating that the term “spherical coordinates” in the sentence be changed to “geodetic coordinates.”

Mr. Schaefer called attention to the first full paragraph on page 7 and suggested that the third sentence of the paragraph be revised to read as follows:

> “An example of a portion of a topographic map at a scale of 1 inch equals 100 feet is provided in Figure 1.”

Mr. Burkholder called attention to the last paragraph on page 7, noting the reference to National Map Accuracy Standards. He indicated that these standards were intended to be applicable to hard copy maps and were developed by the Federal government before the digital computer age. He observed that spatial data accuracy in the digital arena is a major issue being discussed within various national professional organizations—such as the American Society of Civil Engineers, Geomatics Division—because the National Map Accuracy Standards are not applicable to the manipulation of digital spatial data. Chairman Bauer indicated that, in his opinion, the acid test of the accuracy of digital spatial data was whether or not the data when printed out in hard copy form met the National Map Accuracy Standards or other specified standards such as the Commission cadastral mapping standards. Mr. Stroub agreed and indicated that the practice of Aero-Metric, Inc. was, as appropriate, to simply accompany digital data topographic map files with a statement saying that the data, if printed out, would meet National Map Accuracy Standards. Such a statement and test in effect, he said, encapsuled the related accuracies in the digital data from which the maps are plotted. Chairman Bauer indicated that it was not clear to him what the professional deliberations within the national organizations related to. For example, he asked, are they intended to relate to the accuracy with which computer hardware, such as a digitizer, can plot a point identified by survey coordinates, an accuracy that would probably be expressed as absolute in millimeters; or were they concerned with, for example, the placement of pixels comprising a line map or an orthophotograph in an absolute or in a relative position. In any case, as a practical matter, he said the National Map Accuracy Standards and the Commission standards for cadastral mapping had served well as applied to production of the base maps required for the development of the land information and public works management systems within the Region.

Mr. Stroub called attention to the cost figures for topographic and cadastral mapping given on pages 9 and 10. He noted that the figures given were reasonable approximations of the costs entailed in preparing the maps concerned to the Commission's high standards, and that the total costs of transforming the foundational elements of good parcel-based land information and public works management systems given were realistic. He noted that those costs could be significantly reduced, but only by lowering the Commission recommended standards.

In answer to a question by Mr. Burkholder, Chairman Bauer indicated that the report did indeed provide an alternative and less costly means of providing one of the foundational elements concerned, namely through the substitution of orthophotographs for topographic line maps. Mr. Evenson noted that the report also indicated that there were commercially available transformation programs that could be used for the transformation of some types of attribute data contained in the system files, but such programs if applied to transform the foundational elements could significantly degrade the quality and utility of the land information and public works managements systems that are based upon those elements. Mr. Evenson concluded his observation by indicating that the report does not state or imply that "everything" in such systems would need to be replaced even in "starting over."

Mr. Schaefer importantly observed that realistically it is simply impossible to truly "start over" with an existing spatial data system. Firstly, he said, such systems contain invaluable historic data of a specified level of accuracy. Secondly, he said, no matter what standards—including specification of the datums to be used—are adopted at the initiation of a system, between the time of initiation and time of completion of the system, events – especially changing technology – will require adaptation of, or fundamental change in, the system concerned. He noted that the need for change actually may be a perceived need, as opposed to an actual need, and that consequently a need exists to educate users of the systems. Mr. Evenson agreed and indicated that the report was intended in part to be educational. He noted that experience has indicated that land information system managers are sometimes asked questions by users that they are unable to answer, as for example: “Why can’t we move to a new datum?” If the response is because migration is too costly, the next question asked often is: “How much would it indeed cost?” The report is intended to respond to these questions, providing system managers with information needed to respond to such questioning users.

Mr. Stroub indicated that in his opinion the report is an excellent one, and should help questioning users to better understand the implications of migrating to a new system. The need for education of not only users, but also of the surveying, engineering, and land information system communities will obviously not end with the publication of the report. He indicated that he is often appalled by the lack of understanding of the accuracies built into the systems through the foundational elements and of the implications of those accuracies. Chairman Bauer agreed, noting that the Commission in a related matter had published detailed instructions on how to use GPS technology with the legacy datums, yet Commission staff are often confronted by surveyors and engineers who do not know that GPS technology can be readily used with the legacy datums.

Mr. Burkholder called attention to the last paragraph on page 9 and first partial paragraph on page 10 and questioned the procedure described for the production of the needed cadastral maps, given that the maps would be in digital form. Chairman Bauer indicated that the Commission practice was to produce the needed cadastral maps by having an experienced registered land surveyor plot each parcel within a U.S. Public Land Survey System (USPLSS) quarter section on dimensionally stable base material. In the procedure the coordinate positions of the (USPLSS) section, quarter section and center of section corners and the lengths and bearings of the quarter section lines are used as control. The attendant topographic maps are used for needed ground truth, that is for providing accurate locations and configurations of such planimetric features as building outlines; roadway pavements; railway tracks; fences; and lake, stream and water course shorelines and thread lines. The property boundary lines are plotted by the land surveyor in much the same way as the boundaries would be surveyed in the field. The process requires an overview of all of the property boundary lines within the quarter section, and substantial analysis, synthesis and experienced judgment are required in the plotting of the lines. The property boundary lines, as plotted on the dimensional stable base material, are then converted to digital format using digitizer hardware. It may be possible, he said, to construct the parcel boundaries directly in digital format by use of computer assisted drafting hardware and software, but this is not how it has been done by the Commission. Mr. Burkholder suggested that the described procedure raised the issue of the need for digital standards. Chairman Bauer indicated that the most fundamental accuracy standards for the cadastral mapping were those given in the paragraph referred to by Mr. Burkholder, just as the National Map Accuracy Standards were the most fundamental standards governing the quality of the Commission topographic maps. Chairman Bauer noted that Commission specifications for both topographic and cadastral mapping also included specifications for the digital file organization, these specifications being essential for the convenient plotting and use of the digital map files.

Mr. Merry indicated that the American Society for Photogrammetry and Remote Sensing (ASPRS) provided detailed model specifications for various types of mapping as did the National Standards for Spatial Data Accuracy (NSSDA). In applying these standards, he said, it is important to identify whether they are to be applied to hard copy or digital formats, and especially important to identify the publication scale at which the standards are to be applied. However, he agreed with Chairman Bauer that references to the National Map Accuracy Standards—with respect to topographic mapping—and to the Commission standards—with respect to cadastral mapping—encapsulated the more detailed digital standards in a practical manner.

Mr. Stroub noted that the NSSDA did not really constitute an accuracy statement, but rather a reporting mechanism; while the National Map Accuracy Standards did indeed constitute an accuracy statement. The former is concerned with the process used to reach an end product; the latter is concerned with the accuracy of that product, an accuracy that can be verified by field test.

Mr. Schaefer observed that the relative position of two points on a map may be more critical than the absolute position of either one. He observed further that in producing boat sheets and nautical charts the U.S. Coast and Geodetic Survey had required that those sheets and charts met National Map Accuracy Standards, at the publication scale. Both hard copy and digital maps, he noted, can be reproduced at larger or smaller scales than intended, but the statement that the map meets National Map Accuracy Standards is applicable only at the originally specified publication scale. Moreover, he said, many factors determine the accuracy of a map, including the specifications governing the original survey and the specifications governing the drafting and the printing processes. Mr. Stroub indicated that these observations related to issues that end product users unfortunately often do not understand. After some further discussion, it was agreed that the following sentence should be added at the end of the first partial paragraph on page 10:

> “The constructed maps are then transformed into digital form.”

Mr. Burkholder called attention to the second full paragraph on page 10 and suggested that the last sentence be revised to read as follows:

> “This practice introduces a small difference that could be up to 0.01 foot in 100 feet in the values concerned.”

Mr. Schaefer called attention to the last sentence of the first partial paragraph on page 14 and questioned whether the use of orthophotographs in the preparation of the plan portion of public works construction plans and profiles had been universally abandoned. He noted, that WisDOT in fact uses only line maps in the plan portion of the construction project documents concerned. Mr. Stroub indicated that the statement was too broad and that orthophotographs are used by some engineers and agencies for the plan portion of the construction project documents. Upon further discussion it was agreed that the sentence should be revised to read as follows:

> “For this reason, the use of orthophotographs in the preparation of the plan portion of the public works construction plans and profiles has been found by some engineers and agencies to be less satisfactory than the use of line maps.”

Mr. Schaefer called attention to the penultimate sentence on page 14 and suggested that it be revised to read as follows:

> “Software – known as VERTCON – available from NGS permits the conversion between the new and legacy vertical datums at an expected mean error of approximately 0.02 meter, adequate for land information system purposes and for some land and engineering survey purposes.”

Mr. Schaefer suggested that the text be expanded to include a similar reference to NADCON.

In answer to a question by Mr. Evenson, Mr. Merry indicated that some “handheld” GPS devices will let the user select a desired datum, including NAD 27, and will provide absolute positions to within a few meters. Mr. Evenson observed that in the discussions with land information system managers concerning dynamic versus static spatial location needs, no one had raised the use by the police, fire, emergency medical, and transit agencies of GPS receivers that operate on the NAD 27 datum.

Mr. Burkholder called attention to the last sentence of the penultimate paragraph on page 15, and suggested that the word “legacy” be used to modify “foundational elements.”

Mr. Schaefer called attention to the penultimate sentence in the first partial paragraph on page 18 and indicated that the correct terminology was “Continuously Operating Reference Stations (CORS).”

Mr. Simon suggested that the first sentence of the first partial paragraph on page 18 be stressed, given that he has experienced widespread misunderstanding concerning this issue. After further discussion it was agreed that the sentence concerned should be used to begin a new paragraph and that the paragraph should read as follows:

> “The Commission staff has demonstrated that it is possible to utilize GPS technology cost effectively with the existing CORS network established within the Region by WisDOT to obtain accurate State Plane Coordinate Values on the NAD 27 datum. Moreover, the Commission has provided a detailed example of how GPS technology and the WisDOT CORS system can be used to obtain accurate coordinate values of survey points on the NAD 27 datum. This example is set forth in Appendix G of SEWRPC Technical Report No. 49, *Bidirectional Transformation of Legacy and Current Survey Control Data Within Southeastern Wisconsin*, May 2010.

Chairman Bauer noted that at this point in its deliberations, the Task Force had completed its review of the Commission report and would now begin its review of the appended Aero-Metric, Inc. report.

Mr. Schaefer suggested that Aero-Metric use the same format for the datum identification notations that it was agreed would be used in throughout the Commission report. Mr. Schaefer noted that the NAVD 88 (2007) adjustment and the NAVD 88 (2012) adjustment differed by up to 2.4 centimeters in some locations, even though WisDOT followed NGS directions in making the 2007 adjustment. The 2012 adjustment, he noted, closely matches the 1991 adjustment, but does not match the 2007 adjustment at all points. In answer to a question by Mr. Merry, Mr. Schaefer indicated that the 2007 adjustment would remain as an historic vertical realization even though the NGS is not publishing superseded data – a problem for users. Mr. Merry observed that it was important to users that superseded control survey data be made readily available and not lost over time. This was important because users may have relied in the past on the superseded data and those data may, therefore, be involved in needed transformations.

In answer to a question by Mr. Schaefer, Mr. Merry indicated that the resurvey was based upon NAD 83 (2007) because this was the direction given to Aero-Metric, Inc. by the Commission staff. Chairman Bauer indicated that NAD 83 (2007) and NAVD 88 (2007) had been specified as the new datums concerned at the request made during the discussions held with land information system managers operating within the Region. Mr. Schaefer observed that if and when funding for a resurvey became available, the migration should be from the legacy datums to the latest current national datums in effect at the time. Upon further discussion it was agreed that the following footnote should be added to the last paragraph on page 18 of the Commission report.

> "The land information managers concerned specifically requested that the desired cost estimate be made for the migration of the existing control survey network within the Region from the legacy datums to the NAD 83 (2007) and NAVD 88 (2007) datums. The costs presented in this report are applicable to the migration of the legacy datums in use within the Region to any of the NAD 83 and NAVD 88 realizations. It is not known at this time if those costs would also apply to the proposed ITRF-17 datum. The different datum realizations and the new datum would provide different coordinate values and different elevations between the datum realizations and the new datum as well as between the various datum realizations and new and the legacy datums."

In answer to a question by Mr. Burkholder, Mr. Merry indicated that the proposed resurvey would result in an independent redetermination of both the horizontal and vertical position of the survey points and bench marks within the Region. The positions and elevations of the CORS stations in and adjacent to the Region would provide the framework for the resurvey and data related to the CORS stations would be perpetuated in the resurvey. In answer to a further question by Mr. Burkholder, Mr. Merry indicated that the resurvey would not, in effect, be duplicating work done in previous height modernization programs since those programs never included the USPLSS corners within the Region. In answer to a yet further question by Mr. Burkholder, Mr. Merry indicated that the resurvey would establish a primary control survey network consisting of the monumented USPLSS township corners thereby providing a stable framework within which the monumented section, quarter section and center of section corners can be located to a specified level of accuracy. Being tied to the CORS network through the township corners, all of the survey data can be adjusted to achieve the desired level of accuracy.

Mr. Burkholder indicated that in his opinion the approach being taken for the resurvey was imminently sound, but he questioned if it could be afforded.

Chairman Bauer questioned whether it would be possible to simply occupy each USPLSS corner with GPS equipment to obtain new horizontal and vertical positions for the corners. Mr. Merry indicated that could be another approach, but it would not provide the corner positions to within the desired accuracy levels. In answer to a question by Mr. Burkholder, Mr. Schaefer indicated that he accepted Mr. Merry's response to Chairman Bauer and also the approach proposed to be taken to the resurvey.

Chairman Bauer indicated that in his opinion establishing the primary network as proposed was intuitively desirable because it provided an integrated framework and control throughout the Region and facilitated proceeding with the work on a township or series of townships basis. Mr. Merry agreed, indicating that the proposed primary network would facilitate a sub-regional approach in a manner that the CORS network alone would not. He noted that the need for and value of the proposed primary network was set forth on page 2. Mr. Schaefer observed that if the resurvey were carried out on a township by township basis, the coordinate values of the USPLSS corners along common township boundaries might differ slightly.

[Secretary Note: the meeting was adjourned at 12:00 noon for lunch and reconvened at 12:30 P.M.]

In answer to a question by Chairman Bauer, Mr. Merry indicated that the use of base stations located within each township was proposed to support the resurvey of the section, quarter section and center of section corners at the desired level of corner position accuracy.

Mr. Burkholder noted that the results of the resurvey would be recorded in various documents some of which were specifically identified in the Aero-Metric report. He indicated that he assumed that these documents would be available in both hard copy and digital form and asked which of the two forms would be considered the primary form. Chairman Bauer indicated that the Commission's practice made the hard copy versions of the "Record of U.S. Public Land Survey Control Station" – an example of which was given on an Exhibit C on page 7 – and the "Control Survey Summary Diagram" – an example of which was given in Exhibit E on page 12, the primary record. Digital versions of these documents were made available on the Commission website. Chairman Bauer observed that hard copy documents were the only form that was known to be permanent in that digital records had not yet stood the test of time for permanence. Changes over time in computer hardware and attendant software may make digital records inaccessible if an agency such as the Commission cannot at some future time afford costly changes in available hardware and software that may be needed to continue to use the data. Indeed, the Commission had experienced the loss of topographic mapping of a large area within the Region due to a combination of deterioration of the electronic data and changes in hardware and software. Fortunately the Commission had retained hard copies of the maps on dimensionally stable base material. Natural events such as major sun spot bursts, or acts of vandalism by "hackers" may actually destroy the data.

Mr. Schaefer noted that from a land surveying perspective, the County Surveyor is the one that is required to certify to the information shown on the "Record of U.S. Public Land Survey Control Station" sheets. He noted that while the geodetic survey engineers involved in a resurvey could provide some of the information displayed in the upper portion of the sheet, they could not certify to the information concerning the perpetuation of the public land survey corners given in the lower portion of the sheet. He asked how this problem was intended to be resolved. Chairman Bauer indicated that, in his opinion, this was indeed a problem in that while the geodetic survey engineer involved in the resurvey would be provided with the latest version of these sheets for use in recovering and occupying the monumented corners, the condition of the corner monumentation—whether or not the monuments had been disturbed or destroyed—would have to be observed and noted on the sheets together with observed changes in the witness marks and bench mark monumentation. The annotated sheets would then have to be provided to the County Surveyor and Commission staff, which then would have to perform the necessary monument perpetuation work, draft new location sketches and certificates, and return the revised sheets to the geodetic survey engineer who would then have to revisit the corners concerned. For this, as well as for, among other reasons, he indicated he was concerned that Aero-Metric may have underestimated the cost of the survey work and of the attendant documentation. Mr. Merry indicated that he was confident that the cost estimates provided were adequate.

Mr. Schaefer noted that the "Record of U.S. Public Land Survey Control Station" form as reproduced on page 7 did not identify the unit of measurement and suggested that a statement be added to the form in an appropriate location indicating that all measurements were given in U.S. Survey Feet. He noted that practitioners and users are increasingly unaware of the difference between the U.S. Survey Foot and the International Foot, a difference which in some cases may lead to significant difference in control survey data. Mr. Merry agreed, indicating that he was aware of some software programs that did not operate correctly because of confusion between the two units of measurements.

Mr. Schaefer also suggested that the angles and bearings be properly expressed on the form as for example: 1° 24′ 03″.

Chairman Bauer called attention to the first paragraph on page 10 describing an alternative means for the resurvey of the vertical control network. He observed that in his opinion, this approach was convoluted, replete with uncertainty, and a poor substitute for the first alternative described on page 8. He said, however, it was less costly and for that reason, at Mr. Merry's recommendation, had been included in the total cost of a migration.

In answer to a question by Mr. Schaefer, Chairman Bauer indicated it was the Commission long-standing practice to provide a combination scale and sea level reduction factor on the control survey summary diagrams. He noted that it was apparently difficult enough for some practicing surveyors and public works engineers to understand the use of this single factor, much less the use of two separate factors for scale and sea level reduction. Indeed, he said, WisDOT project engineers have apparently never been able to understand the implication and use of the factor giving rise to the use of county coordinate systems. In answer to a further question by Mr. Schaefer, Chairman Bauer indicated that both ground and grid level distances are given on the diagrams. In answer to a further question and comment by Mr. Schaefer, Chairman Bauer indicated that the combination factor is indeed computed for the center of the USPLSS six-section diagram, and that ground level distances on the perimeters of the six-section areas would differ slightly from distances on the perimeters of adjacent diagrams. Mr. Burkholder noted, however, that the grid distances would be identical.

CONCLUSION AND ADJOURNMENT

There being no further questions or comments Chairman Bauer noted that the Task Force had completed its charge to critically review the preliminary draft of SEWRPC Technical Report, *Cost Estimate For Resurvey of Regional Control Survey Network*, September 2012*;* including the *Report on Cost Resurvey of SEWRPC Control Survey Network* and other appendices provided by the formal Aero-Metric, Inc. report. These reports and appendices will now become SEWRPC Memorandum Report No. 206. He indicated that unless he hears to the contrary, the two reports as amended may be considered to meet with the approval of the Task Force members.

Chairman Bauer indicated that the Task Force members would receive a preliminary draft of the minutes of the meeting for review and comment. Proposed changes should be provided to the Commission staff either by means of a returned annotated hard copy, or by means of a transmitted annotated electronic copy. The necessary changes will then be made, and a final copy of the minutes provided to the Task Force members together with a self-addressed, stamped, post-card ballot, indicating the members approval, disapproval, or conditional approval of the final draft of the minutes. He noted that the minutes would be published as an Appendix to the Memorandum Report.

Chairman Bauer once more thanked the Task Force members for their diligent review of the two reports and for their contribution of their time, knowledge and experience as a public service to the work of the Commission.

The meeting was adjourned at 2:30 P.M.

Respectfully Submitted,

Lynn G. Heis
Task Force Recording Secretary

[Secretary Note: The foregoing minutes were approved by the Task Force by mail ballot, the last ballots being returned on November 19, 2012.]

KWB/lgh/dps
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