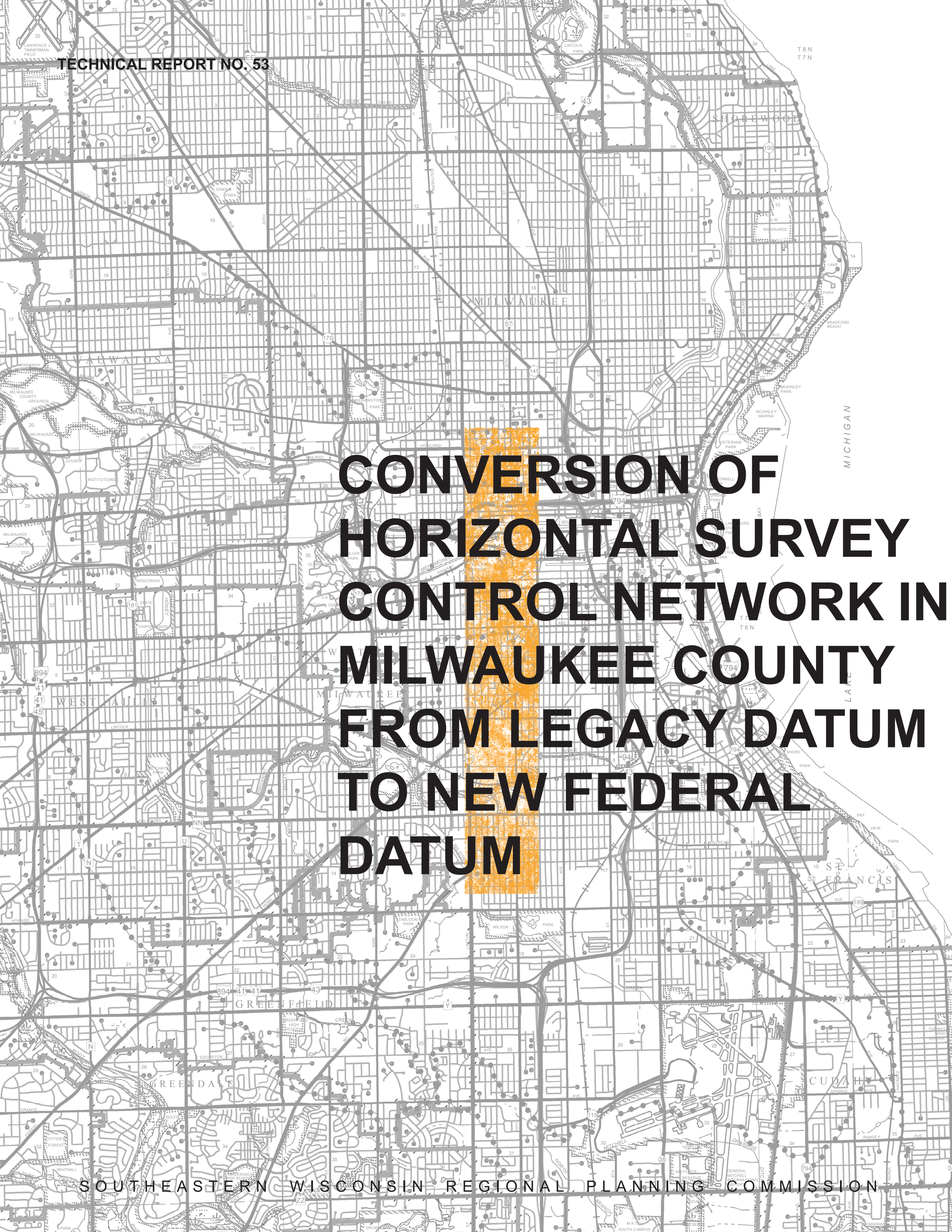
TECHNICAL REPORT NO. 53



CONVERSION OF HORIZONTAL SURVEY CONTROL NETWORK IN MILWAUKEE COUNTY FROM LEGACY DATUM TO NEW FEDERAL DATUM

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Prepared by the

Southeastern Wisconsin Regional Planning Commission
W239 N1812 Rockwood Drive
P.O. Box 1607
Waukesha, WI 53187-1607
www.sewrpc.org

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

W239 N1812 ROCKWOOD DRIVE • PO BOX 1607 • WAUKESHA, WI 53187-1607• TELEPHONE (262) 547-6721
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STATEMENT OF THE EXECUTIVE DIRECTOR

As noted in the introductory section of this report, the Regional Planning Commission has, since 1964, recommended to the governmental agencies operating within the Region the creation and 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, as a basis for the development of automated, parcel based, land information and public works management systems within the Region. With the assistance of the constituent counties and municipalities, the recommended survey control system has been extended over the entire seven-county Region. All of the 11,753 U.S. Public Land Survey System corners within the Region have been monumented and the coordinate positions and elevations of the corners determined to a high level of survey accuracy. The survey control network has been widely used in the Region for over 50 years.

All of the horizontal survey control work within the Region has been referenced to the North American Datum of 1927. The Federal Government in 1983 created a new horizontal datum known as the North American Datum of 1983. To facilitate the use of the new datum within the Region by such agencies as may determine to do so, the Commission developed procedures for the conversion of the horizontal survey control network within the Region from the legacy datum to the new Federal datum. These procedures, and the issues concerned with datum conversion were addressed in a number of Commission publications, the latest being SEWRPC Memorandum Report No. 206, entitled, "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," and its Addendum, October 2012 and August 2015, respectively.

In 2016, the county land information council managers within the Region collegially determined to proceed with datum conversion, and to request Commission assistance in carrying out the conversion using the Commission-developed procedures to provide survey grade coordinates for all of the U.S. Public Land Survey System corners within the Region. On January 19, 2017, the Commission entered into an agreement with Milwaukee County governing the conversion of the survey control network within the County from the legacy horizontal datum to the new Federal datum. This report describes the datum conversion completed under the agreement. Importantly, the results demonstrated that the procedure developed by the Commission provided the desired level of accuracy in the converted coordinate positions of the U.S. Public Land Survey System corners, a level of accuracy meeting national Third Order Class I Standards.

It is also important to note that the completed datum conversion provides two of the four foundational elements of the county and municipal land information and public works management systems within the Region, a datum and an attendant map projection. The other two foundational elements—large scale topographic maps and real property boundary—cadastral—maps will also require conversion, as will the attribute data contained in the land information and public works management systems within the Region.

Respectfully submitted,

Michael G. Hahn

Michael G. Hahn
Executive Director

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INTRODUCTION AND BACKGROUND

Since 1961, 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, specifically for Milwaukee County, since 1989, as a basis for the development of a county automated, parcel-based, land information and public works management system.[1] The recommended survey control system requires the remonumentation of the U.S. Public Land Survey System corners within the Region and the establishment of State Plane Coordinates for those corners. The system also includes the establishment of elevations for the monumented corners and for related auxiliary bench marks to provide a reliable vertical survey control network fully integrated with the horizontal network.

Through the cooperative efforts of the Commission and its constituent counties and municipalities, the recommended survey control system has been extended over the entire seven-county Region. All of the 11,985 U.S. Public Land Survey System corners within the Region have been remonumented, and the coordinate positions, and elevations of the remonumented corners have been determined to a high level of accuracy. The resulting survey control network has been widely used for over 50 years in the preparation of large-scale topographic and cadastral maps, in the conduct of land and engineering surveys, and in the creation of parcel-based land information and public works management systems within the Region.

All of the coordinate positions of the remonumented stations of the survey control network within the Region have been referenced to the North American Datum of 1927 (NAD 27), a datum established and promulgated by the Federal government. The datum is based upon the Clarke Spheroid of 1866, a spheroid which fits the North American Continent and the Southeastern Wisconsin Region well. The elevations of the remonumented stations and of ancillary benchmarks have been referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929), 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 survey control 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). The new horizontal datum was subsequently readjusted to create NAD 83 (2011). The Federal government in 1977 similarly determined to undertake a readjustment of the national vertical survey control network, and to adopt a new vertical datum known as the North American Vertical Datum of 1988 (NAVD 88).

REEVALUATION OF REGIONAL SURVEY CONTROL NETWORK

The Commission has long maintained that adoption and use of the new Federal datums within the Region does not provide any significant technical advantages over the continued use of the legacy datums. Nevertheless, in response to concerns raised by some practicing land surveyors and some county land information system managers about the continued use of the legacy datums within the Region, the Commission in 2012 prepared SEWRPC

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[1] *See SEWRPC Community Assistance Planning Report No. 177,* "Feasibility Study for a Milwaukee County Automated Mapping and Land Information System"*, October 1989.*

Memorandum 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,"* October 2012. In response to the specific requests of some county land information system managers, the report presented a procedure for converting the legacy datums within the Region to the newer datums and presented an estimate of the cost of such conversion meeting land and engineering survey accuracy standards. Given the high estimated cost of the envisioned conversion, and the lack of offsetting monetary benefits, the report recommended the continued use of the legacy datums within the Region. Despite this recommendation, some practicing land surveyors and some county land information system managers continued to express a desire to pursue datum conversion within the Region and to request Commission assistance in making the desired conversion. Given this continuing concern, and given the significant changes in surveying technology that had taken place since publication of Memorandum Report 206, the Commission in 2015 undertook a reevaluation of the findings and recommendations presented in that report. The findings of that reevaluation are set forth in an Addendum to Memorandum Report No. 206 entitled, *"Revised 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,"* and published in August 2015.

PROCEDURES FOR DATUM CONVERSION

The procedure for the conversion of the horizontal control survey network within the Region from the legacy to the new datums as originally proposed in Memorandum Report No. 206, was based upon the technology available in 2012 to provide a high order of accuracy in control survey work. The originally proposed conversion procedure utilized a series of static Global Positioning System (GPS) observations[2] to provide new primary and secondary survey control networks within the Region. Based upon these higher order networks, new State Plane Coordinate positions on the North American Datum of 1983 (NAD 83) would then be obtained by occupying all of the stations comprising the network for further GPS observations. The procedure, while providing a high level of accuracy in the new position data, was costly – probably prohibitively so – considering the lack of known offsetting benefits.

Significant changes in surveying technology occurred after publication of SEWRPC Memorandum Report No. 206. These changes warranted reconsideration of the procedure originally proposed for datum conversion in that report. The changes in surveying technology included the completion by the Wisconsin Department of Transportation of a Continuously Operating Reference Stations (CORS) network within the State of Wisconsin, coupled with the development and acceptance of Virtual Reference Station (VRS) Technology.[3] This technology eliminated: l) the need to rely upon static GPS observations for the datum conversion work, and 2) the need for measurements to be made simultaneously by a roving GPS receiver and an attendant base station or stations. These two changes—while continuing to require occupation of all stations in the control survey network with a roving receiver—presented significant increases in the efficiency of the necessary field survey work, with attendant significant reductions in cost.

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[2] *In 2012 Global Positioning System observations intended to provide high orders of accuracy, known as static positioning surveys, utilized two or more receivers simultaneously receiving data from the system satellites. These data included dual-frequency carrier phase measurements that in effect represented distances. Post processing of the simultaneous observations provided precise vectors from which coordinate positions could be computed. The static survey procedure required stations in a network to be occupied and attendant data observed for significant periods of time—ranging from approximately 15 minutes to one hour.*

[3] *Virtual Reference Station technology consists of a system of hardware and software designed to facilitate real-time global positioning system measurements based on a network of reference stations known as continuously operating reference stations—performing in the role of the base stations in static global positioning surveys. The network of receivers is linked to a computation center, and each station contributes its raw data to help create network-wide models necessary to provide accurate positioning of the roving receiver. The primary benefit of the technology is that it permits real-time kinematic positioning using a single receiver in the field while achieving centimeter-level accuracy.*

Importantly, the Commission staff working with its veteran consulting geodesist—Mr. Earl F. Burkholder, P.S., P.E.—developed a unique procedure for horizontal datum conversion which minimized the number of control survey stations that had to be occupied by a roving GPS receiver to accomplish the desired conversion work. This procedure combines GPS field observations on a carefully selected minimum number of control survey stations in a subarea of the Region—such as a U.S. Public Land Survey System township—with measurement data collected in the original control surveys conducted within the Region to create the legacy survey control network. The procedure uses these legacy measurement data to compute the coordinate positions of the remaining unoccupied stations in the subarea. This unique procedure is more fully described in Appendix C of the Addendum to Memorandum Report No. 206. That Appendix C is reproduced as an appendix to this report.

REVISED COMMISSION RECOMMENDATION

The work accomplished in preparing the Addendum to MR No. 206 resulted in a change in the long-standing recommendation of the Commission to continue the use of the legacy survey datums within the Region. The Commission continued to recognize that the benefits of the conversion of the legacy datums to the new Federal datums remained largely intangible. However, the conversion using the procedure developed by the Commission staff would have one very important, although still intangible, benefit namely, the conversion procedure would retain the relative positions of all of the control survey stations within the Region as given by the legacy lengths and bearings of the one-quarter section lines, thus preserving the integrity of the legacy horizontal control survey network within the Region. This benefit was considered sufficient to warrant incurring the relatively modest cost of a horizontal data conversion. The Addendum accordingly recommended that each of the individual county land information system managers within the Region determine whether or not their agency desired to proceed with the conversion of the horizontal datum in use within the Region from NAD 27 to NGVD 83 (2011). If it was determined to proceed, it was indicated that the work could be accomplished by the Commission under contract with the counties concerned, the work being done on a county-by-county basis.

Similarly, the land information system managers would have to determine whether or not their agency desired to proceed with the conversion of the vertical datum in use within the Region from NGVD 29 to NGVD 88 (2012). However, in this case, the conversion would have to be carried out for the Region as a whole. Therefore, all seven county land information system agencies within the Region would have to agree to proceed, and would have to agree upon a distribution of the cost between the counties concerned. If it was determined to proceed, it was indicated that the work could be accomplished by the Commission under contract jointly with all seven county land information systems.

In considering the conversion of the horizontal datum within the Region, it was apparently understood by all concerned that such conversion would entail only two of the four foundational elements of a parcel-based land information or public works management system—the datum and related map projection and the control survey network. Each of the other two foundational elements—the topographic maps for ground truth, and the parcel based cadastral maps, together with the assembled attribute data, will require recompilation, or in the alternative, some form of adjustment if those elements are to be useable with coordinate positions on the new datum. Coordinate positions referred to the new horizontal datum cannot be plotted on the legacy topographic and cadastral maps of the existing land information and public works management systems within the Region. The conversion of the other two foundational elements and the attribute data of the existing systems will constitute the major portion of the costs of the conversion as set forth in SEWRPC Memorandum Report No. 206.

COUNTY ACTION

In a series of informal meetings held during the course of calendar year 2016, the seven county land information managers, acting on behalf of their agencies, unanimously agreed to proceed on a county-by-county basis with the conversion of the legacy horizontal datum in use within the Region to the new Federal datum. The managers similarly agreed unanimously to proceed cooperatively with the conversion of the vertical datum.

Accordingly, on January 31, 2017, Milwaukee County entered into an agreement with the Commission under which the Commission would convert the State Plane Coordinate positions of all 1,134 U.S. Public Land Survey System or System extension corners within County from the legacy datum—NAD 27—to the new Federal datum—NAD 83 (2011). The conversion was to be accomplished by the procedure set forth in Appendix C of the Addendum to SEWRPC Memorandum Report No. 206. As already noted, a copy of Appendix C of the Addendum to Memorandum Report No. 206 is provided in an appendix to this report. The work was to be accomplished in a period of two years from the date of the agreement. The "deliverables" under the agreement were to include, in addition to the new coordinate positions of the U.S. Public Land Survey system corners, revised control survey station record sheets—commonly known as dossier sheets—for each corner, and new control survey summary diagrams, each diagram covering six U.S. Public Land Survey System sections. This report documents the work accomplished and the products created and delivered under the agreement.

FIELD PROCEDURES

Following the procedure set forth in the appendix to this report, 160 remonumented U.S. Public Land Survey System or System extension corners were recovered and occupied for GPS measurement. The location of these corners is shown on Figure 1 appended. The State Plane Coordinates of the occupied stations referred to the new Federal horizontal datum are given in Table 1 appended.

The remonumented corners were recovered using the Record of U.S. Public Land Survey Control Station sheets – so called dossier sheets – on file with the Commission. To insure that the recovered monuments truly marked the corner locations concerned, a minimum of three tie distances to extant witness corners were measured, and the distances checked against those shown on the dossier sheets.

The equipment used in the field work included a Trimble R-8 Global Positioning System Receiver (GPS receiver) coupled with a Trimble TSC2 Data Collector.[4] During the observations, the GPS receiver was linked to the CORS network created and operated by the Wisconsin Department of Transportation within and adjacent to the County by ordinary mobile telephones. This combination of equipment is known to be capable of obtaining National Geodetic Survey (NGS) Third Order, Class I network accuracy or better, equivalent to an accuracy of 1 part in 10,000 for the lengths of the one-quarter section lines. The GPS equipment was supported by a TopCon Model GPT-3002LW total station instrument capable of obtaining NGS Third Order Survey accuracy, and by 200 foot long steel tapes required to measure tie distances to witness corners, and to make attendant miscellaneous angular and distance measurements.

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[4] *The first artificial satellite geodetic positioning and navigation system was developed by the U.S. Department of Defense (DOD) for military purposes and became operational in 1983. Initially the DOD deliberately degraded the satellite transmissions to limit the positional accuracy for civilian use. In 1996 the DOD ended the degradation policy and made the system available for civilian use in a fully accurate mode – thus promoting the use of the system in surveying applications. The DOD system is the satellite positioning system that has become known by the acronym GPS for the term Global Positioning System. The GPS instrumentation used by the Commission in the creation of portions of the legacy regional survey control network exclusively used the DOD system. Since the completion of the legacy survey control network in the Region, other satellite based positioning and navigation systems have been created, such as systems by the European Union, Russia, and China. State-of-the-art receiving instruments can utilize signals from all of these satellite systems. The systems in combination are identified as the Global Navigation Satellite System (GNSS). The receiving instrumentation used in the conduct of the field work for the Milwaukee County datum conversion project utilized the GNSS system and did so in order that the observations would be made in a manner consistent with the instrumentation used by the Wisconsin Department of Transportation in conjunction with its system of Continuously Operating Reference Stations (CORS) within the Region.*

OFFICE COMPUTATIONS

The procedure for the datum conversion envisions utilizing the legacy lengths of the one-quarter section lines and the interior angles of the one-quarter sections in combination with the measured NAD 83 (2011) coordinates of the corners occupied for GPS measurement. The initial step in the computation process involved a least squares adjustment of the recorded legacy data to identify any errors or blunders that may exist in the legacy data. This initial step was intended to provide an absolutely “clean” data set for use in subsequent computations. A small number of relatively minor errors in the existing network were found together with a very small number of blunders involving such issues as transposition of integers, and the errors and blunders were corrected. The positions of a cluster of stations grouped within an identified area were found to only marginally meet the required network accuracy and were targeted for adjustment. In addition, the positions of two isolated stations were found to be in error, requiring correction.

The second step in the computation process involved combining the measured NAD 83 (2011) coordinate positions with the legacy lengths of the one-quarter section lines and the legacy interior angles of the one-quarter sections in a least squares adjustment to compute the NAD 83 (2011) coordinate positions of the 974 non-occupied corners within the County. The resulting NAD 83 (2011) State Plane Coordinates, and the lengths and bearings of the one-quarter section lines were recorded on the six section control summary diagrams covering the County.

PROBLEM AREAS

Analyses of the results of the initial computation of the positions of the survey control stations—U.S. Public Land Survey System corners—indicated that the positions of a cluster of stations within an approximately nine square mile area did not meet the required network accuracy. The discrepancies found involved the survey connections from the errant stations to stations in the surrounding network. The area concerned is shown on Figure 2. It contains 47 stations of which 14 were readjusted. The discrepancies found in the positions of the stations within the area ranged with respect to Northings, from a negative 0.42 to a positive 0.61 feet; and with respect to Eastings, from a negative 0.21 to a positive 0.26 feet. Even though these discrepancies marginally meet the required network accuracy standards, it was decided to adjust the positions as expressed on both the legacy datum and the new Federal datum to more fully meet the required standard.

Further analyses indicated that the discrepancies found could most likely be attributed to survey measurement or as computational errors made in the conduct of the precise traverses used to determine the legacy positons of the stations concerned. To correct the discrepancies found, the errant stations—corners—were, to the extent practicable at the time, occupied for GPS measurements. The occupied stations are shown on Figure 2. The GPS measurements together with the positions of the stations in the surrounding network were then used to adjust the position of the errant stations. These adjusted positions referred to the legacy datum were entered on revised legacy six section survey control summary diagrams, and for the adjusted positions referred to the new Federal datum were entered on new survey control summary diagrams prepared under the project.

In addition to the station position discrepancies found within the problem area previously described, discrepancies in the location of eleven stations were also found. These stations are also shown on Figure 2. The discrepancies range from a minimum of a negative 0.52 feet to a maximum of a positive 0.54 feet. Investigation of the history of the monumentation marking the positions of these stations, as given by the dossier sheets on record with the Commission for these stations, indicated that the discrepancies found were probably caused by blunders in the traverse surveys originally made to locate the positions of the corners. The positions of these eleven stations as given on both the revised legacy survey control summary diagrams and on the new diagrams prepared under this project reflect the true position of the corners.

FIELD VERIFICATION OF COMPUTED CORNER POSITIONS

To check the accuracy of the computed survey control station coordinates, an approximately 16 percent random sample of the stations—U.S. Public Land Survey System corners—within the County for which the coordinates were computed was selected. The location of the 186 sample stations are shown on Figure 3 appended. The monuments marking the U.S. Public Land Survey System corners comprising the sample were recovered and occupied with GPS instrumentation to obtain independently measured coordinate values for the corners. The measured coordinate positions were then compared with the computed positions. The results are set forth in Table 2. Review of the data presented in Table 2 indicates that the largest difference between a measured and a computed northing was 0.21 feet, while the largest difference between a measured and a computed easting was 0.22 feet. The root mean square error between the measured and the computed Northings was 0.10 feet and between the Eastings was 0.09 feet. The test confirmed the validity of the NAD 83 (2011) coordinates as determined by the conversion procedure. It is interesting to note that the shift in the geographic positions of the legacy and new Federal horizontal datums within the Region, as measured by the spherical coordinate differences of a centrally located station within the County is about 0.067 seconds of latitude, and 0.297 seconds of longitude, equivalent to about 6.6 feet and 29.2 feet, respectively.

CONCLUSION

It may be concluded that the horizontal datum conversion procedure developed by the Commission staff provides an accurate and cost-effective means for the conversion of the legacy horizontal datum in use within the Region to the presently promulgated Federal datum. As described in this report, using the procedure the extant horizontal survey control network within Milwaukee County was successfully converted from the legacy datum—NAD 27—to the presently promulgated Federal datum—NAD 83 (2011). Independent field observations demonstrated that the converted State Plane Coordinate positions of the monumented County survey control network met Third Order Class 1 Standards—providing linear distance closures of 1 part in 10,000 or better. Importantly, the procedure preserves the validity of the survey control network referred to the legacy datum, the lengths of one-quarter section lines being essentially identical under the two datums.

In accordance with the agreement entered into between the County and the Commission governing the horizontal datum conversion, the following survey control data and materials were delivered in digital format to the County together with copies of this report:

- A revised copy of the "Record of U.S. Public Land Survey Control Station"—so called dossier sheet—for each of the 1,134 survey control stations—monumented U.S. Public Land Survey System corners—within the County. The revised dossier sheets provide the State Plane Coordinates of the corner concerned referred to both the—NAD 27 and NAD 83 (2011) datums. An example of a revised dossier sheet is provided in Figure 4 appended.

- New six section survey control summary diagrams covering the County. These 47 diagrams show the monumented U.S. Public Land Survey Station corners, the State Plane Coordinates of those corners referred to NAD 83 (2011), the grid and ground level lengths of the one-quarter section lines, the interior angles of the one-quarter sections and the bearings of the one-quarter section lines, and the ground level area of the one-quarter sections. An example of a survey control summary diagram is provided in Figure 5 appended.

TABLES AND FIGURES

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Table 1

MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS TO CONTROL DATUM CONVERSION COMPUTATIONS – COORDINATES GIVEN ARE REFERRED TO NAD 83 (2011)

Corner Number	Northing	Easting	Corner Number	Northing	Easting
1	440490.24	2484902.01	36	416616.58	2487570.44
2	440674.90	2490194.07	37	414682.45	2527323.24
3	440867.40	2495462.13	38	412070.79	2529969.45
4	441022.02	2500769.46	39	411945.89	2514121.35
5	441188.99	2508711.48	40	411776.69	2503537.06
6	441388.77	2521932.34	41	411617.69	2495564.90
7	441539.57	2529782.33	42	409391.40	2527358.09
8	438557.78	2519290.16	43	409423.61	2529995.97
9	438631.41	2516674.54	44	409467.84	2532637.08
10	437569.43	2484933.15	45	406780.85	2532684.47
11	435904.90	2529815.24	46	406758.52	2530066.97
12	433039.13	2503416.66	47	406645.18	2524777.21
13	432834.29	2495459.96	48	406608.44	2522157.14
14	432312.43	2484957.52	49	406549.76	2514135.14
15	429676.05	2484965.43	50	406452.13	2508793.24
16	430630.83	2516710.94	51	406260.10	2500727.40
17	430539.08	2521964.05	52	403968.94	2519498.12
18	430649.59	2532517.37	53	404039.80	2527448.78
19	427913.90	2524613.29	54	404200.18	2535386.44
20	427834.90	2508735.10	55	401426.51	2530118.03
21	427722.70	2503418.77	56	401389.60	2527464.41
22	427427.50	2492828.01	57	401303.83	2519518.84
23	425244.90	2521998.60	58	400622.85	2492667.46
24	425286.85	2527279.69	59	397597.49	2485028.16
25	422635.74	2527291.21	60	398361.38	2503531.73
26	422615.58	2524647.93	61	398949.48	2538048.25
27	422616.32	2519375.55	62	395904.55	2514254.08
28	422624.51	2514056.93	63	393596.53	2536164.33
29	422386.55	2500746.13	64	390308.31	2501020.74
30	419973.77	2516752.58	65	387013.83	2485195.99
31	419946.22	2522027.62	66	387914.71	2514382.11
32	419990.29	2527306.31	67	388025.22	2519687.85
33	417344.12	2527315.23	68	388256.48	2533858.55
34	417275.44	2514077.05	69	387346.51	2532912.77
35	417241.87	2511402.05	70	385166.29	2509121.36

Table 1 (continued)

Corner Number	Northing	Easting
71	272573.39	2564864.48
72	272104.51	2549891.30
73	272080.60	2534074.27
74	272067.29	2518398.54
75	271529.73	2502449.89
76	271215.14	2486655.91
77	270698.11	2470802.08
78	270127.88	2449724.02
79	266941.47	2428716.53
80	267773.54	2457685.19
81	267069.75	2557949.75
82	266815.21	2528886.92
83	261877.04	2560846.48
84	261535.06	2550255.41
85	261530.86	2534388.04
86	261360.61	2515955.94
87	260975.65	2502721.23
88	260599.72	2484304.30
89	259444.55	2444827.54
90	258916.60	2423701.80
91	258194.88	2439577.99
92	256388.78	2555676.80
93	256013.70	2513446.72
94	255560.02	2494932.24
95	254502.73	2455534.68
96	251002.39	2424006.31
97	248663.24	2437232.24
98	245719.05	2424158.08
99	243706.79	2447969.63
100	237963.66	2429625.88
101	232775.37	2432370.25
102	227240.35	2424515.53
103	227324.03	2427182.80
104	227444.26	2429831.95
105	227509.51	2432479.63
106	227567.28	2435132.42
107	227621.02	2437754.84
108	227674.89	2440377.21
109	227748.68	2443013.18
110	227828.55	2445646.05

Corner Number	Northing	Easting
111	340412.65	2509689.58
112	337496.62	2496456.37
113	338249.37	2538632.95
114	338276.03	2546628.23
115	335605.02	2543961.06
116	335500.42	2533384.11
117	335472.25	2520075.93
118	334977.57	2501772.64
119	334737.56	2488541.70
120	332201.28	2496486.11
121	330302.74	2538617.13
122	329953.09	2512303.43
123	327517.25	2522718.39
124	325008.05	2543803.35
125	324894.02	2533279.69
126	324806.52	2517643.14
127	324402.30	2501862.93
128	324129.55	2485922.33
129	318881.48	2493966.58
130	319306.31	2509779.69
131	319547.82	2525336.53
132	319662.29	2538499.13
133	319719.80	2546377.38
134	319726.78	2548576.76
135	318597.65	2549013.89
136	317093.33	2549738.64
137	317083.31	2549035.90
138	317071.14	2546408.57
139	315231.08	2549062.40
201	313358.01	2486092.38
202	313443.37	2488734.96
203	313507.54	2491374.48
204	313588.52	2494012.72
205	313669.60	2496650.92
206	313749.55	2499285.00
207	313829.23	2501919.28
208	313894.02	2504554.65
209	313957.22	2507189.39
210	314025.08	2509829.51
211	314082.24	2512461.31

Table 1 (continued)

Corner Number	Northing	Easting
212	314146.97	2515091.44
213	314194.45	2517710.35
214	314214.29	2520169.64
215	314224.66	2522802.07
216	314252.65	2525429.24
217	314268.94	2528063.74
218	314288.82	2530696.01
219	314307.43	2533327.64

Corner Number	Northing	Easting
220	314319.53	2535954.65
221	314349.11	2538577.44
222	314376.96	2541199.50
223	314405.31	2543821.60
224	314420.87	2546441.21
225	314456.63	2549073.49
226	314479.51	2550728.81

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 1.

Table 2

MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS TO VERIFY COMPUTED COORDINATE POSITION

Corner Number		Northing	Easting
1	Computed	440568.65	2487476.70
	GPS Observed	440568.62	2487476.64
	Difference	-0.03	-0.06
2	Computed	440570.85	2487549.04
	GPS Observed	440570.82	2487549.07
	Difference	-0.03	0.03
3	Computed	440672.07	2490122.03
	GPS Observed	440672.07	2490122.04
	Difference	0.00	0.01
4	Computed	440867.34	2495456.87
	GPS Observed	440867.22	2495456.90
	Difference	-0.12	0.03
5	Computed	441020.40	2500713.24
	GPS Observed	441020.47	2500713.29
	Difference	0.07	0.05
6	Computed	441187.91	2508650.39
	GPS Observed	441187.95	2508650.33
	Difference	0.04	-0.06
7	Computed	441387.77	2521875.78
	GPS Observed	441387.80	2521875.70
	Difference	0.03	-0.08
8	Computed	438524.64	2527189.48
	GPS Observed	438524.73	2527189.42
	Difference	0.09	-0.06
9	Computed	438484.25	2521919.30
	GPS Observed	438484.34	2521919.30
	Difference	0.09	0.00
10	Computed	438441.05	2508680.98
	GPS Observed	438441.08	2508680.85
	Difference	0.03	-0.13
11	Computed	438374.25	2506002.05
	GPS Observed	438374.20	2506001.97
	Difference	-0.05	-0.08

Corner Number		Northing	Easting
12	Computed	437926.76	2490128.81
	GPS Observed	437926.87	2490128.81
	Difference	0.11	0.00
13	Computed	435112.63	2487485.38
	GPS Observed	435112.73	2487485.39
	Difference	0.10	0.01
14	Computed	435387.39	2492776.90
	GPS Observed	435387.43	2492776.91
	Difference	0.04	0.01
15	Computed	435580.09	2498083.32
	GPS Observed	435579.92	2498083.23
	Difference	-0.17	-0.09
16	Computed	435855.94	2511378.10
	GPS Observed	435855.86	2511378.10
	Difference	-0.08	0.00
17	Computed	435967.82	2516688.41
	GPS Observed	435967.88	2516688.44
	Difference	0.06	0.03
18	Computed	433247.52	2519313.30
	GPS Observed	433247.67	2519313.49
	Difference	0.15	0.19
19	Computed	433140.98	2508734.50
	GPS Observed	433141.00	2508734.47
	Difference	0.02	-0.03
20	Computed	432626.64	2490163.77
	GPS Observed	432626.43	2490163.89
	Difference	-0.21	0.12
21	Computed	430588.58	2527249.40
	GPS Observed	430588.52	2527249.40
	Difference	-0.06	0.00
22	Computed	427615.66	2498119.47
	GPS Observed	427615.67	2498119.47
	Difference	0.01	0.00

Table 2 (continued)

Corner Number		Northing	Easting
23	Computed	427177.36	2487517.56
	GPS Observed	427177.33	2487517.64
	Difference	-0.03	0.08
24	Computed	422023.36	2490183.41
	GPS Observed	422023.34	2490183.45
	Difference	-0.02	0.04
25	Computed	422512.70	2508726.46
	GPS Observed	422512.60	2508726.52
	Difference	-0.10	0.06
26	Computed	419467.11	2492865.66
	GPS Observed	419466.94	2492865.52
	Difference	-0.17	-0.14
27	Computed	417001.33	2498151.56
	GPS Observed	417001.28	2498151.53
	Difference	-0.05	-0.03
28	Computed	417098.30	2503452.97
	GPS Observed	417098.33	2503452.82
	Difference	0.03	-0.15
29	Computed	414693.84	2529638.64
	GPS Observed	414693.96	2529638.63
	Difference	0.12	-0.01
30	Computed	414667.18	2524691.58
	GPS Observed	414667.31	2524691.56
	Difference	0.13	-0.02
31	Computed	414348.02	2498177.99
	GPS Observed	414347.92	2498178.08
	Difference	-0.10	0.09
32	Computed	411452.47	2490258.75
	GPS Observed	411452.51	2490258.65
	Difference	0.04	-0.10
33	Computed	411683.39	2498225.95
	GPS Observed	411683.42	2498225.98
	Difference	0.03	0.03
34	Computed	411757.91	2500872.16
	GPS Observed	411758.00	2500872.25
	Difference	0.09	0.09

Corner Number		Northing	Easting
35	Computed	411842.89	2508813.83
	GPS Observed	411842.84	2508813.96
	Difference	-0.05	0.13
36	Computed	409467.66	2532631.39
	GPS Observed	409467.74	2532631.40
	Difference	0.08	0.01
37	Computed	409423.87	2530009.35
	GPS Observed	409423.84	2530009.42
	Difference	-0.03	0.07
38	Computed	409391.85	2527401.23
	GPS Observed	409391.93	2527401.23
	Difference	0.08	0.00
39	Computed	409371.59	2524758.70
	GPS Observed	409371.63	2524758.72
	Difference	0.04	0.02
40	Computed	408884.25	2492963.85
	GPS Observed	408884.21	2492963.83
	Difference	-0.04	-0.02
41	Computed	408869.94	2492522.23
	GPS Observed	408869.83	2492522.25
	Difference	-0.11	0.02
42	Computed	408797.37	2490309.81
	GPS Observed	408797.47	2490309.76
	Difference	0.10	-0.05
43	Computed	408782.50	2489833.47
	GPS Observed	408782.52	2489833.40
	Difference	0.02	-0.07
44	Computed	405913.52	2489893.15
	GPS Observed	405913.50	2489893.08
	Difference	-0.02	-0.07
45	Computed	405979.26	2492570.20
	GPS Observed	405979.23	2492570.15
	Difference	-0.03	-0.05
46	Computed	406151.30	2497975.35
	GPS Observed	406151.20	2497975.30
	Difference	-0.10	-0.05

Table 2 (continued)

Corner Number		Northing	Easting
47	Computed	406342.88	2503443.62
	GPS Observed	406342.91	2503443.62
	Difference	0.03	0.00
48	Computed	406726.28	2530100.66
	GPS Observed	406726.23	2530100.67
	Difference	-0.05	0.01
49	Computed	401543.45	2535410.02
	GPS Observed	401543.42	2535409.87
	Difference	-0.03	-0.15
50	Computed	401231.81	2514182.67
	GPS Observed	401231.76	2514182.62
	Difference	-0.05	-0.05
51	Computed	401116.66	2508838.27
	GPS Observed	401116.57	2508838.31
	Difference	-0.09	0.04
52	Computed	400835.92	2498064.32
	GPS Observed	400836.04	2498064.17
	Difference	0.12	-0.15
53	Computed	395514.97	2498215.92
	GPS Observed	395514.96	2498215.84
	Difference	-0.01	-0.08
54	Computed	395826.54	2508894.14
	GPS Observed	395826.34	2508894.04
	Difference	-0.20	-0.10
55	Computed	395995.76	2519579.59
	GPS Observed	395995.71	2519579.65
	Difference	-0.05	0.06
56	Computed	396047.58	2524871.87
	GPS Observed	396047.42	2524871.83
	Difference	-0.16	-0.04
57	Computed	396134.14	2530170.88
	GPS Observed	396134.10	2530171.09
	Difference	-0.04	0.21
58	Computed	396226.74	2535456.84
	GPS Observed	396226.79	2535456.79
	Difference	0.05	-0.05
59	Computed	390925.72	2534238.64
	GPS Observed	390925.64	2534238.85
	Difference	-0.08	0.21
60	Computed	390760.03	2524937.91
	GPS Observed	390759.88	2524937.96
	Difference	-0.15	0.05
61	Computed	390678.12	2519650.10
	GPS Observed	390678.19	2519650.30
	Difference	0.07	0.20
62	Computed	390475.52	2508991.95
	GPS Observed	390475.42	2508991.81
	Difference	-0.10	-0.14
63	Computed	389745.27	2487653.78
	GPS Observed	389745.19	2487653.97
	Difference	-0.08	0.19
64	Computed	387274.00	2493076.26
	GPS Observed	387274.08	2493076.44
	Difference	0.08	0.18
65	Computed	388203.36	2530252.42
	GPS Observed	388203.28	2530252.45
	Difference	-0.08	0.03
66	Computed	384448.43	2487850.29
	GPS Observed	384448.54	2487850.34
	Difference	0.11	0.05
67	Computed	382038.01	2495885.10
	GPS Observed	382037.81	2495885.27
	Difference	-0.20	0.17
68	Computed	382357.86	2503896.48
	GPS Observed	382357.97	2503896.49
	Difference	0.11	0.01
69	Computed	382726.74	2519787.00
	GPS Observed	382726.72	2519786.92
	Difference	-0.02	-0.08
70	Computed	382836.09	2525063.93
	GPS Observed	382836.09	2525063.94
	Difference	0.00	0.01

Table 2 (continued)

Corner Number		Northing	Easting
71	Computed	380181.69	2522481.51
	GPS Observed	380181.74	2522481.42
	Difference	0.05	-0.09
72	Computed	380116.64	2519846.83
	GPS Observed	380116.81	2519846.79
	Difference	0.17	-0.04
73	Computed	379884.72	2511423.64
	GPS Observed	379884.76	2511423.59
	Difference	0.04	-0.05
74	Computed	379753.64	2506604.03
	GPS Observed	379753.79	2506604.06
	Difference	0.15	0.03
75	Computed	379502.15	2498644.55
	GPS Observed	379502.03	2498644.48
	Difference	-0.12	-0.07
76	Computed	374738.99	2509399.34
	GPS Observed	374738.86	2509399.37
	Difference	-0.13	0.03
77	Computed	375035.26	2519946.66
	GPS Observed	375035.05	2519946.48
	Difference	-0.21	-0.18
78	Computed	372455.20	2525166.24
	GPS Observed	372455.08	2525166.38
	Difference	-0.12	0.14
79	Computed	371599.76	2493542.19
	GPS Observed	371599.80	2493542.18
	Difference	0.04	-0.01
80	Computed	369732.40	2519988.59
	GPS Observed	369732.42	2519988.71
	Difference	0.02	0.12
81	Computed	369967.98	2530456.69
	GPS Observed	369967.94	2530456.72
	Difference	-0.04	0.03
82	Computed	369882.61	2527769.23
	GPS Observed	369882.66	2527769.05
	Difference	0.05	-0.18

Corner Number		Northing	Easting
83	Computed	369727.44	2519993.63
	GPS Observed	369727.43	2519993.77
	Difference	-0.01	0.14
84	Computed	369443.02	2509472.07
	GPS Observed	369443.05	2509471.93
	Difference	0.03	-0.14
85	Computed	369126.71	2498843.90
	GPS Observed	369126.83	2498843.72
	Difference	0.12	-0.18
86	Computed	368862.06	2488293.05
	GPS Observed	368862.04	2488292.98
	Difference	-0.02	-0.07
87	Computed	366167.50	2485297.15
	GPS Observed	366167.52	2485297.07
	Difference	0.02	-0.08
88	Computed	366195.99	2488335.60
	GPS Observed	366195.97	2488335.52
	Difference	-0.02	-0.08
89	Computed	367345.02	2533192.75
	GPS Observed	367345.16	2533192.75
	Difference	0.14	0.00
90	Computed	367373.15	2535844.36
	GPS Observed	367373.10	2535844.31
	Difference	-0.05	-0.05
91	Computed	364571.66	2527846.79
	GPS Observed	364571.68	2527846.83
	Difference	0.02	0.04
92	Computed	364415.63	2520029.19
	GPS Observed	364415.47	2520029.02
	Difference	-0.16	-0.17
93	Computed	364161.77	2509526.48
	GPS Observed	364161.84	2509526.48
	Difference	0.07	0.00
94	Computed	361200.73	2498923.44
	GPS Observed	361200.90	2498923.53
	Difference	0.17	0.09

Table 2 (continued)

Corner Number		Northing	Easting
95	Computed	361654.10	2514843.63
	GPS Observed	361654.14	2514843.66
	Difference	0.04	0.03
96	Computed	362092.12	2535881.24
	GPS Observed	362092.00	2535881.32
	Difference	-0.12	0.08
97	Computed	362144.48	2538508.93
	GPS Observed	362144.48	2538508.98
	Difference	0.00	0.05
98	Computed	358925.56	2509561.53
	GPS Observed	358925.73	2509561.61
	Difference	0.17	0.08
99	Computed	358263.28	2488334.72
	GPS Observed	358263.19	2488334.68
	Difference	-0.09	-0.04
100	Computed	358510.34	2498940.01
	GPS Observed	358510.30	2498939.96
	Difference	-0.04	-0.05
101	Computed	358720.64	2504243.16
	GPS Observed	358720.67	2504243.19
	Difference	0.03	0.03
102	Computed	358874.25	2509510.61
	GPS Observed	358874.35	2509510.72
	Difference	0.10	0.11
103	Computed	359116.21	2520103.95
	GPS Observed	359116.08	2520103.83
	Difference	-0.13	-0.12
104	Computed	359261.83	2527942.30
	GPS Observed	359261.95	2527942.39
	Difference	0.12	0.09
105	Computed	359386.38	2533308.43
	GPS Observed	359386.37	2533308.29
	Difference	-0.01	-0.14
106	Computed	359438.26	2535938.97
	GPS Observed	359438.27	2535938.80
	Difference	0.01	-0.17

Corner Number		Northing	Easting
107	Computed	359490.00	2538566.91
	GPS Observed	359489.87	2538567.05
	Difference	-0.13	0.14
108	Computed	359564.54	2541213.24
	GPS Observed	359564.37	2541213.26
	Difference	-0.17	0.02
109	Computed	356923.22	2541274.02
	GPS Observed	356923.36	2541273.93
	Difference	0.14	-0.09
110	Computed	356838.66	2538627.54
	GPS Observed	356838.77	2538627.53
	Difference	0.11	-0.01
111	Computed	356783.46	2535996.23
	GPS Observed	356783.46	2535996.31
	Difference	0.00	0.08
112	Computed	356667.24	2530678.42
	GPS Observed	356667.33	2530678.47
	Difference	0.09	0.05
113	Computed	356605.40	2528003.78
	GPS Observed	356605.50	2528003.98
	Difference	0.10	0.20
114	Computed	356552.97	2525382.56
	GPS Observed	356553.16	2525382.70
	Difference	0.19	0.14
115	Computed	353701.36	2512265.44
	GPS Observed	353701.37	2512265.51
	Difference	0.01	0.07
116	Computed	353132.93	2493677.95
	GPS Observed	353132.84	2493677.99
	Difference	-0.09	0.04
117	Computed	353652.61	2512315.86
	GPS Observed	353652.56	2512315.95
	Difference	-0.05	0.09
118	Computed	353821.30	2520195.21
	GPS Observed	353821.09	2520195.30
	Difference	-0.21	0.09

Table 2 (continued)

Corner Number		Northing	Easting
119	Computed	353914.77	2525435.65
	GPS Observed	353914.98	2525435.81
	Difference	0.21	0.16
120	Computed	354116.99	2536050.31
	GPS Observed	354116.92	2536050.41
	Difference	-0.07	0.10
121	Computed	351632.52	2541446.44
	GPS Observed	351632.59	2541446.34
	Difference	0.07	-0.10
122	Computed	351542.37	2538758.76
	GPS Observed	351542.42	2538758.73
	Difference	0.05	-0.03
123	Computed	351479.50	2536100.14
	GPS Observed	351479.57	2536100.04
	Difference	0.07	-0.10
124	Computed	351267.45	2525487.99
	GPS Observed	351267.44	2525488.11
	Difference	-0.01	0.12
125	Computed	350788.92	2504316.50
	GPS Observed	350788.86	2504316.52
	Difference	-0.06	0.02
126	Computed	350644.91	2499007.84
	GPS Observed	350645.00	2499007.93
	Difference	0.09	0.09
127	Computed	348367.71	2512310.18
	GPS Observed	348367.77	2512310.11
	Difference	0.06	-0.07
128	Computed	348538.49	2520255.74
	GPS Observed	348538.36	2520255.56
	Difference	-0.13	-0.18
129	Computed	348583.32	2522885.33
	GPS Observed	348583.16	2522885.31
	Difference	-0.16	-0.02
130	Computed	348621.70	2525531.31
	GPS Observed	348621.61	2525531.39
	Difference	-0.09	0.08

Corner Number		Northing	Easting
131	Computed	348830.52	2536144.12
	GPS Observed	348830.70	2536144.29
	Difference	0.18	0.17
132	Computed	346448.89	2545077.91
	GPS Observed	346448.89	2545077.96
	Difference	0.00	0.05
133	Computed	346421.04	2544062.39
	GPS Observed	346421.10	2544062.40
	Difference	0.06	0.01
134	Computed	346186.48	2536192.76
	GPS Observed	346186.43	2536192.89
	Difference	-0.05	0.13
135	Computed	346117.93	2533447.77
	GPS Observed	346117.97	2533447.78
	Difference	0.04	0.01
136	Computed	346067.23	2530858.40
	GPS Observed	346067.16	2530858.55
	Difference	-0.07	0.15
137	Computed	346021.32	2528209.58
	GPS Observed	346021.39	2528209.70
	Difference	0.07	0.12
138	Computed	345971.69	2525559.34
	GPS Observed	345971.72	2525559.29
	Difference	0.03	-0.05
139	Computed	345937.45	2522922.73
	GPS Observed	345937.60	2522922.90
	Difference	0.15	0.17
140	Computed	345791.00	2514993.31
	GPS Observed	345790.88	2514993.24
	Difference	-0.12	-0.07
141	Computed	345790.65	2514978.14
	GPS Observed	345790.57	2514978.11
	Difference	-0.08	-0.03
142	Computed	345307.00	2496432.75
	GPS Observed	345307.18	2496432.53
	Difference	0.18	-0.22

Table 2 (continued)

Corner Number		Northing	Easting
143	Computed	343279.91	2514966.04
	GPS Observed	343279.84	2514965.94
	Difference	-0.07	-0.10
144	Computed	343391.96	2517621.10
	GPS Observed	343391.85	2517621.05
	Difference	-0.11	-0.05
145	Computed	343447.43	2520101.17
	GPS Observed	343447.35	2520101.10
	Difference	-0.08	-0.07
146	Computed	343364.08	2528111.54
	GPS Observed	343364.18	2528111.61
	Difference	0.10	0.07
147	Computed	343492.25	2536051.16
	GPS Observed	343492.27	2536051.25
	Difference	0.02	0.09
148	Computed	343552.03	2538698.62
	GPS Observed	343552.12	2538698.58
	Difference	0.09	-0.04
149	Computed	340746.15	2517616.07
	GPS Observed	340746.07	2517615.95
	Difference	-0.08	-0.12
150	Computed	340203.08	2499098.09
	GPS Observed	340203.19	2499097.98
	Difference	0.11	-0.11
151	Computed	340033.29	2488491.22
	GPS Observed	340033.17	2488491.28
	Difference	-0.12	0.06
152	Computed	337643.61	2504412.52
	GPS Observed	337643.77	2504412.51
	Difference	0.16	-0.01
153	Computed	337780.43	2509679.28
	GPS Observed	337780.54	2509679.37
	Difference	0.11	0.09
154	Computed	338089.56	2517616.43
	GPS Observed	338089.43	2517616.29
	Difference	-0.13	-0.14

Corner Number		Northing	Easting
155	Computed	338165.02	2522743.58
	GPS Observed	338165.06	2522743.65
	Difference	0.04	0.07
156	Computed	338075.82	2528059.67
	GPS Observed	338075.73	2528059.60
	Difference	-0.09	-0.07
157	Computed	338197.68	2536008.08
	GPS Observed	338197.85	2536008.04
	Difference	0.17	-0.04
158	Computed	335428.96	2517618.34
	GPS Observed	335428.85	2517618.24
	Difference	-0.11	-0.10
159	Computed	332361.48	2504435.90
	GPS Observed	332361.42	2504435.78
	Difference	-0.06	-0.12
160	Computed	332680.01	2514953.38
	GPS Observed	332679.94	2514953.35
	Difference	-0.07	-0.03
161	Computed	332815.46	2525399.97
	GPS Observed	332815.44	2525399.96
	Difference	-0.02	-0.01
162	Computed	332819.23	2530688.56
	GPS Observed	332819.05	2530688.53
	Difference	-0.18	-0.03
163	Computed	332890.76	2535985.65
	GPS Observed	332890.72	2535985.64
	Difference	-0.04	-0.01
164	Computed	330306.82	2543882.31
	GPS Observed	330306.78	2543882.13
	Difference	-0.04	-0.18
165	Computed	329622.38	2499163.75
	GPS Observed	329622.50	2499163.64
	Difference	0.12	-0.11
166	Computed	329413.44	2488569.15
	GPS Observed	329413.51	2488569.03
	Difference	0.07	-0.12

Table 2 (continued)

Corner Number		Northing	Easting
167	Computed	327083.12	2504466.92
	GPS Observed	327083.26	2504466.72
	Difference	0.14	-0.20
168	Computed	327495.23	2527972.53
	GPS Observed	327495.15	2527972.47
	Difference	-0.08	-0.06
169	Computed	327642.29	2538597.24
	GPS Observed	327642.33	2538597.20
	Difference	0.04	-0.04
170	Computed	324174.78	2493909.31
	GPS Observed	324174.89	2493909.20
	Difference	0.11	-0.11
171	Computed	324095.52	2491268.39
	GPS Observed	324095.68	2491268.31
	Difference	0.16	-0.08
172	Computed	321877.32	2507122.76
	GPS Observed	321877.46	2507122.87
	Difference	0.14	0.11
173	Computed	322226.85	2530610.61
	GPS Observed	322226.76	2530610.53
	Difference	-0.09	-0.08
174	Computed	322286.21	2535909.25
	GPS Observed	322286.18	2535909.20
	Difference	-0.03	-0.05
175	Computed	322355.15	2543762.32
	GPS Observed	322355.06	2543762.23
	Difference	-0.09	-0.09
176	Computed	319711.42	2543727.71
	GPS Observed	319711.40	2543727.75
	Difference	-0.02	0.04

Corner Number		Northing	Easting
177	Computed	319626.82	2535879.27
	GPS Observed	319626.74	2535879.23
	Difference	-0.08	-0.04
178	Computed	319605.48	2533254.02
	GPS Observed	319605.46	2533253.95
	Difference	-0.02	-0.07
179	Computed	319587.09	2530612.03
	GPS Observed	319587.05	2530611.96
	Difference	-0.04	-0.07
180	Computed	319559.38	2527956.38
	GPS Observed	319559.46	2527956.28
	Difference	0.08	-0.10
181	Computed	319533.69	2522725.84
	GPS Observed	319533.74	2522725.89
	Difference	0.05	0.05
182	Computed	319031.23	2499252.15
	GPS Observed	319031.28	2499252.14
	Difference	0.05	-0.01
183	Computed	318787.70	2488678.75
	GPS Observed	318787.72	2488678.95
	Difference	0.02	0.20
184	Computed	316589.35	2507162.94
	GPS Observed	316589.31	2507162.95
	Difference	-0.04	0.01
185	Computed	316790.40	2515074.88
	GPS Observed	316790.31	2515074.98
	Difference	-0.09	0.10
186	Computed	316878.96	2522754.20
	GPS Observed	316878.92	2522754.20
	Difference	-0.04	0.00

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 3

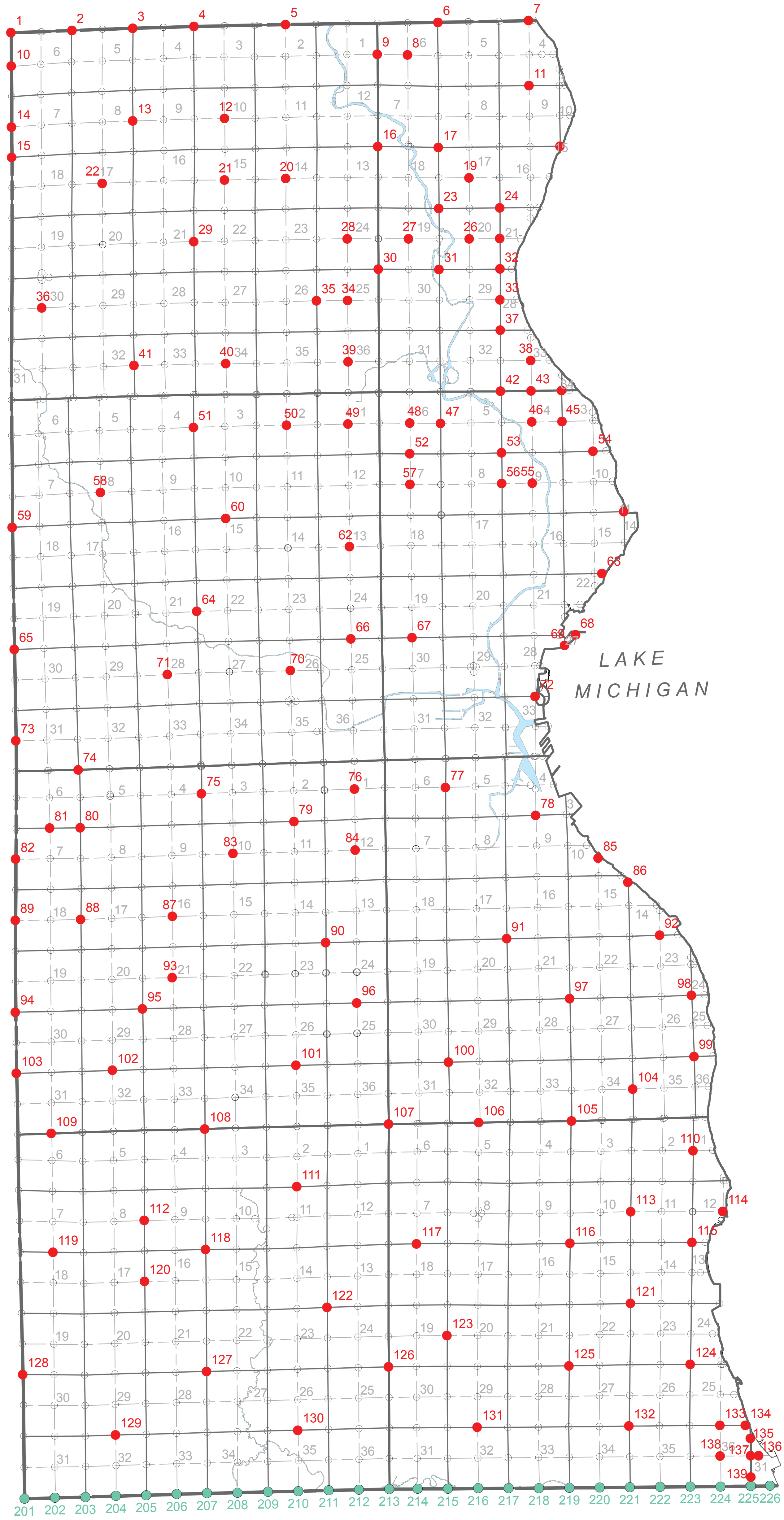
Table 2 (continued)

	Northing	Easting
Sum of Squared Differences................................	1.719	1.682
Average..	-0.001	-0.004
Minimum Difference	-0.210	-0.220
Maximum Difference	0.210	0.210
RMSE...	0.096	0.095
$RMSE_{min}$ / $RMSE_{max}$	0.989	
NSSDA 95% RMSE Accuracy $_r$	0.234	
Note: $RMSE_{min}$ / $RMSE_{max}$ is between 0.6 and 1.0, $Accuracy_r$ = 2.4477 * 0.5 * ($RMSE_{Northing}$ + $RMSE_{Easting}$)		

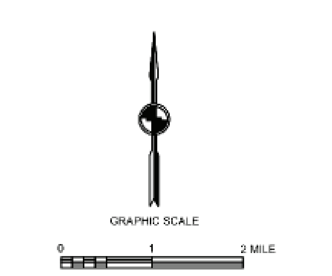
Source: SEWRPC.

FIGURE 1

MAP OF MILWAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO DETERMINE NAD83 (2011) COORDINATES AS BASIS FOR DATUM CONVERSION COMPUTATIONS



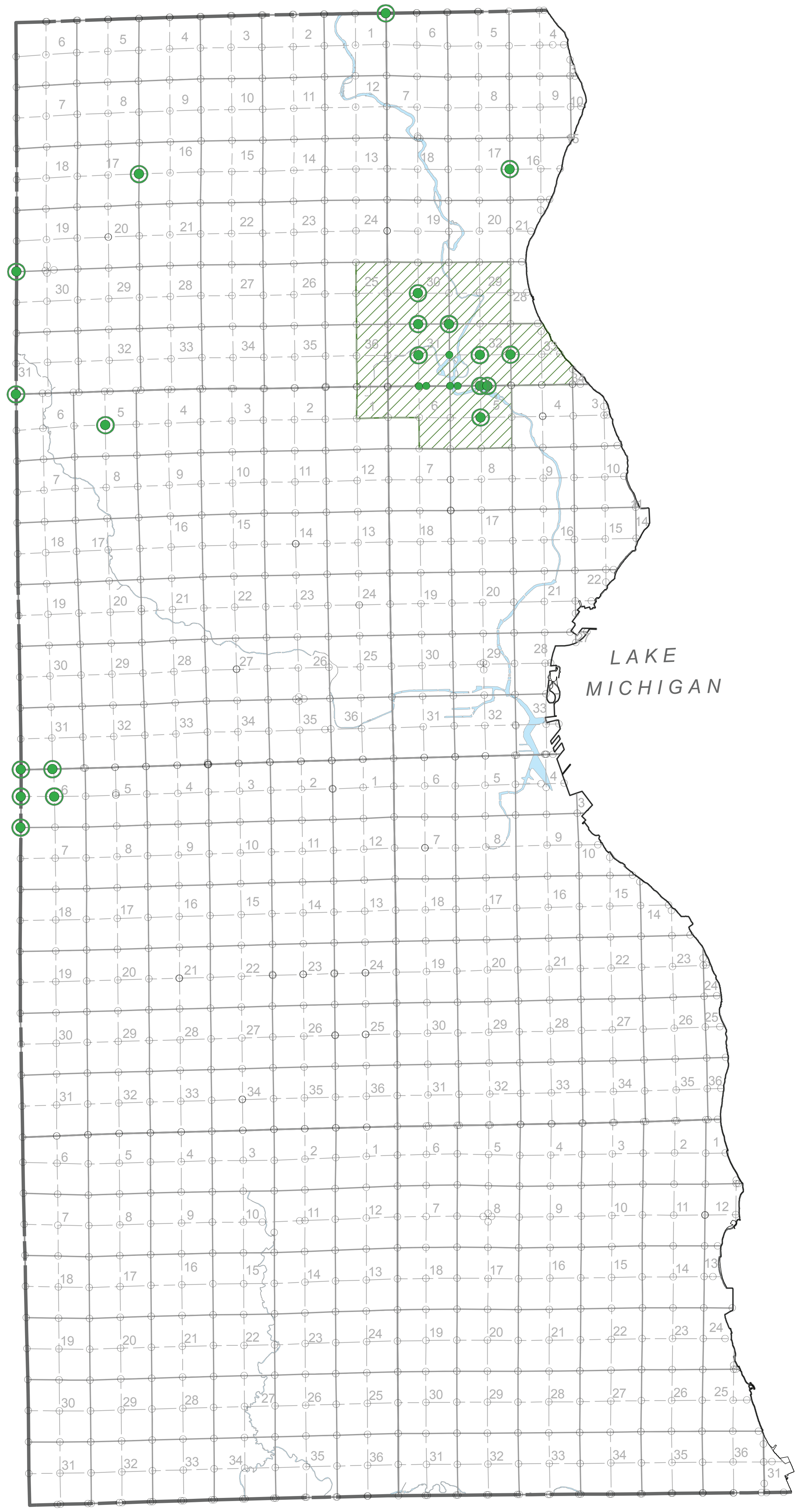
- Monumented USPLSS Corners Recovered and Occupied for GPS Observations to be Used as Basis for Datum Conversion Computations
- Monumented USPLSS Corners Either Recovered and Occupied for GPS Observations or with Adjusted NAD83 (2011) Position Determined in the Racine County Network Adjustment



Source: SEWRPC.

FIGURE 2

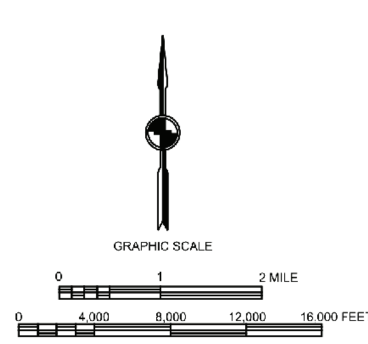
MAP OF MILWAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS THE INITIALLY COMPUTED COORDINATES OF WHICH DID NOT MEET SURVEY CONTROL NETWORK ACCURACY STANDARDS



Problem Area

Monumented Corner Not Meeting Network Accuracy Standards and Readjusted

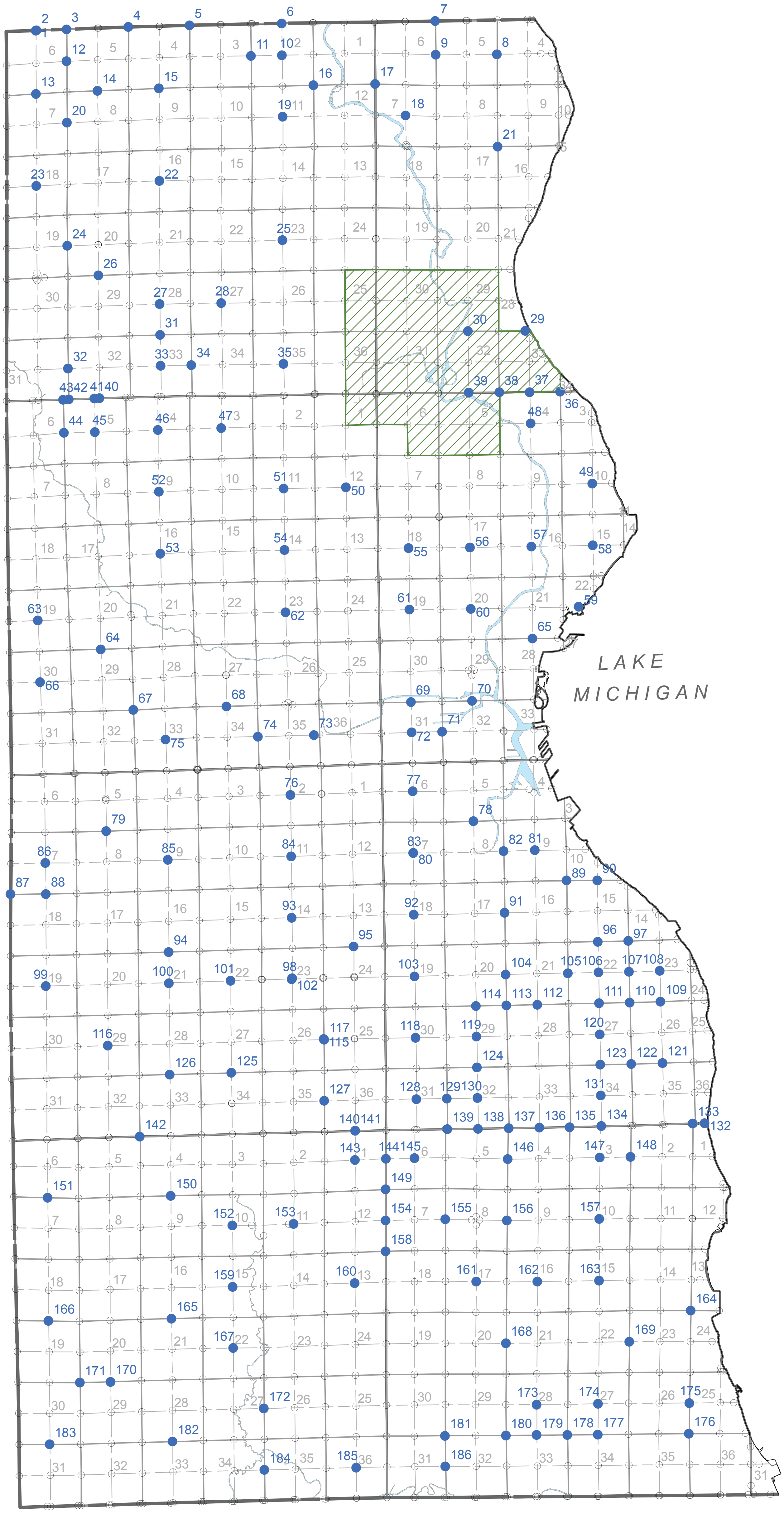
Monumented Corner Not Meeting Network Survey Standards Occupied for GPS Observations and Readjusted



Source: SEWRPC.

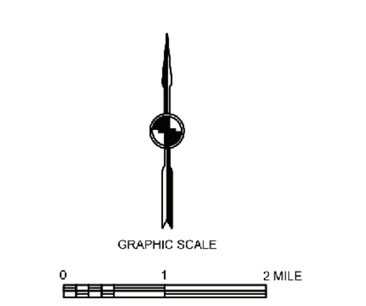
FIGURE 3

MAP OF MILWAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO VERIFY COMPUTED COORDINATE POSITIONS



Problem Area

Monumented USPLSS Corners Recovered and Occupied for GPS Observations Providing Independent Check on the Accuracy of Computed NAD83 (2011) Coordinates



Source: SEWRPC.

Figure 4

SAMPLE DOSSIER

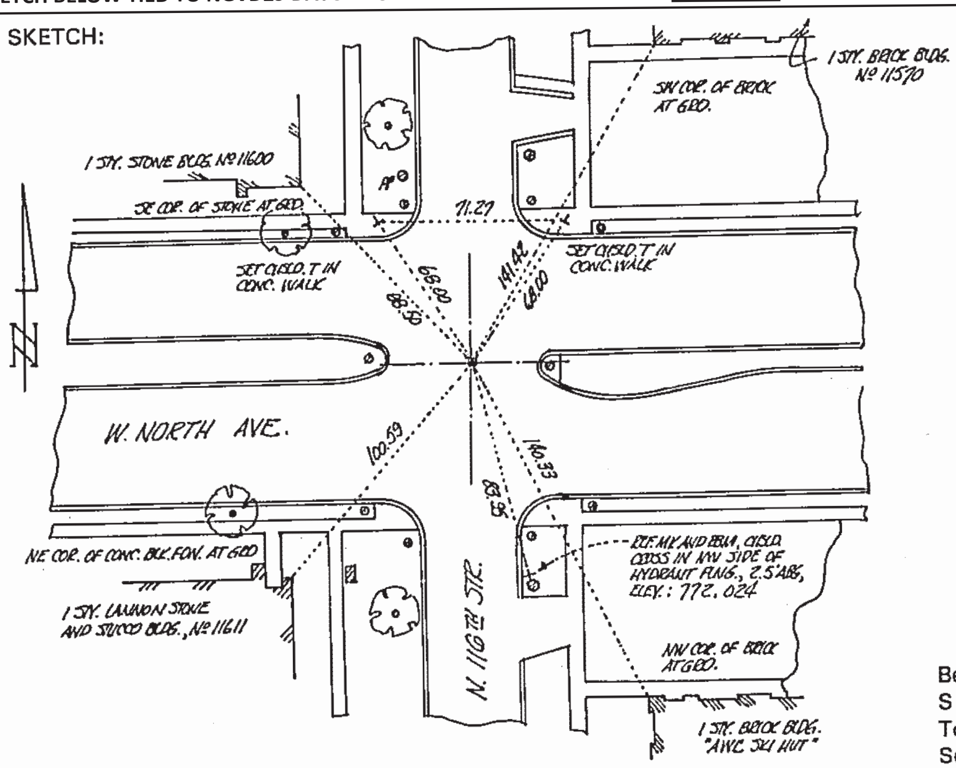
RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

U.S. PUBLIC LAND SURVEY CORNER 18|18 / 19|19 T 07 N, R 21 E, Milwaukee COUNTY, WISCONSIN

HORIZONTAL: NORTH AMERICAN DATUM OF 1927	HORIZONTAL: NORTH AMERICAN DATUM OF 1983/2011
VERTICAL: NATIONAL GEODETIC VERTICAL DATUM OF 1929	VERTICAL: NORTH AMERICAN VERTICAL DATUM OF 1988 (12)
HOR. CONTROL: AERO-METRIC ENGINEERING, INC. 1988	HOR. CONTROL: SEWRPC 2017
VERT. CONTROL:	VERT. CONTROL:
NORTHING: 392,387.19 USFT	NORTHING: 392,396.87 USFT
EASTING: 2,519,095.87 USFT	EASTING: 2,487,558.05 USFT
ELEVATION: 770.118 FT	ELEVATION: FT
HOR. ACCURACY: 3rd ORDER, CLASS I	HOR. ACCURACY: 3rd ORDER, CLASS I (COMPUTED)
VERT. ACCURACY: 2nd ORDER, CLASS II	VERT. ACCURACY:

RBM ELEV. IN SKETCH BELOW TIED TO NGVD29 DATUM. CONVERSION FROM NGVD29 ______ FT DERIVES NAVD88 HEIGHT

LOCATION SKETCH:



Bearing:
S 02-04-13 E
To Center of
Sec. 19-7-21

SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN)
SS
WAUKESHA COUNTY)

As County Surveyor, I hereby certify that I set a concrete monument with SEWRPC brass cap to mark this corner; replacing a broken concrete monument, said concrete monument with WisDOT aluminum cap having been set to mark this corner in 1988 by the City Engineer following street reconstruction; replacing a cast iron plug with cross set in the then existing concrete pavement to mark this corner in 1958 by Walter L. Keil, State Highway Commission of Wisconsin Project Engineer, following street reconstruction; replacing a cast iron plug with cross set in the then existing concrete pavement to mark this corner in 1943 by the Milwaukee County Highway Department following street reconstruction; replacing an iron rod set to mark this corner in 1919 by the Milwaukee County Highway Department following street reconstruction; replacing in turn an old cut limestone monument then marking this corner; that I 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 MILWAUKEE, WIS. LAND SURVEYOR

DATE OF SURVEY: 11 JULY 1992 REGISTERED LAND SURVEYOR S - 157

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION (SEWRPC) 07210900 90 –

CERTIFICATION APPLIES ONLY TO THE LOCATION SKETCH AND SURVEYOR AFFIDAVIT

Source: SEWRPC.

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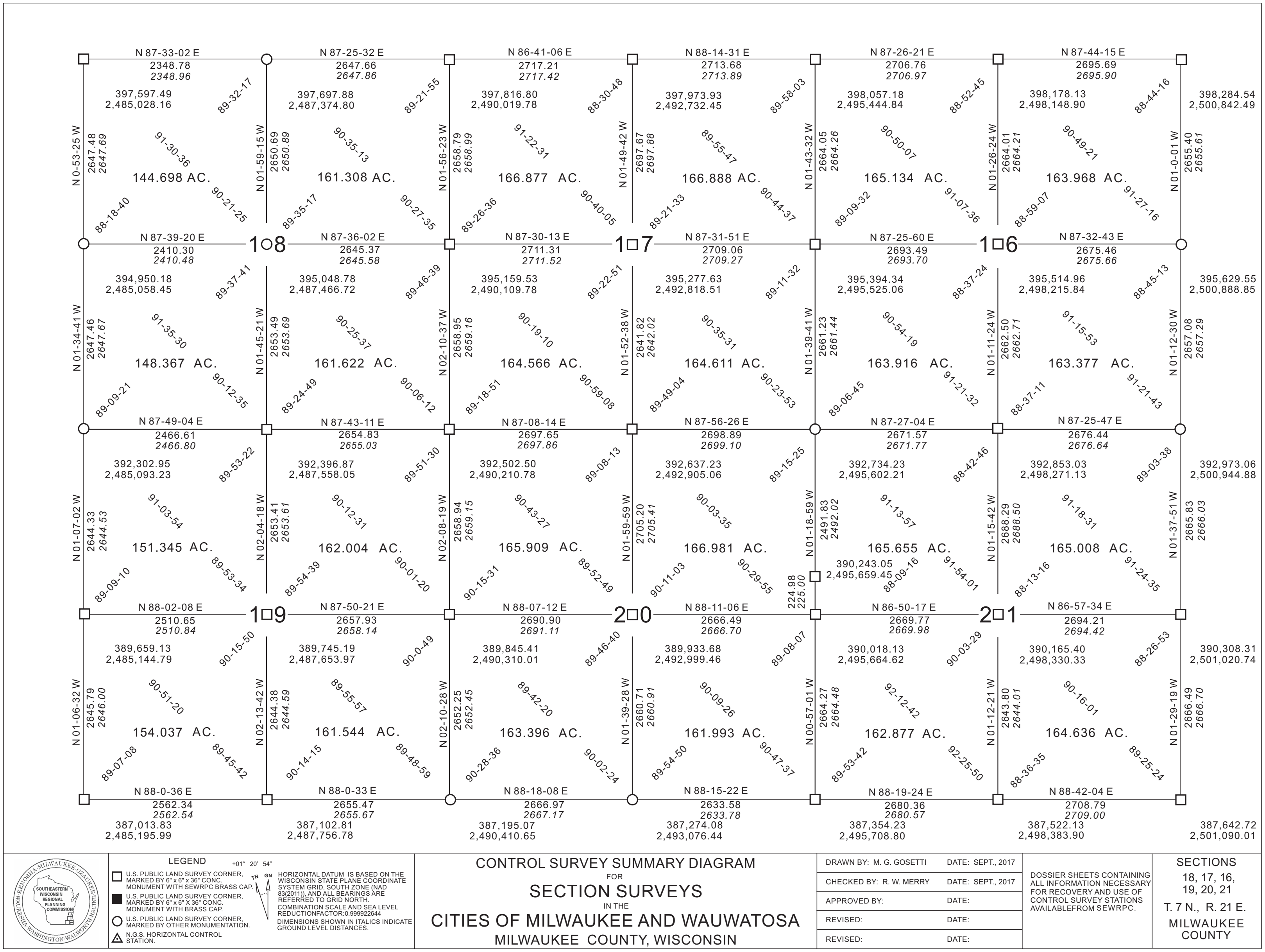
Figure 5

SAMPLE CSSD



Source: SEWRPC.

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Appendix C

From

SEWRPC ADDENDUM TO MEMORANDUM REPORT No. 206
"REVISED ESTIMATE OF THE COSTS OF CONVERTING THE LEGACY DATUMS WITHIN THE REGION TO NATIONAL DATUMS", AUGUST 2015

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INTRODUCTION

The seven-county Southeastern Wisconsin Region has an extensive and accurate network of both horizontal and vertical control survey stations. The integrated horizontal and vertical control survey stations are comprised of the 11,985 U.S. Public Land Survey System (USPLSS) corners within the Region and accessories thereto. The horizontal network is referenced to the North American Datum of 1927 (NAD 27), while the vertical network is referenced to the National Geodetic Vertical Datum of1929 (NGVD 29). The survey methods used to create the horizontal control network ranged from using theodolites and tellurometers to using Global Positioning System (GPS) instrumentation. The survey methods used to create the vertical control network ranged from using differential spirit leveling with invar rods read optically to using coded invar rods read automatically by the level instrument.

The introduction of newer technologies, especially the use of GPS instrumentation, has made the use of the legacy control survey network inconvenient when relating to newer datums created by the Federal government. The Commission continues to maintain the legacy control survey network in five of the seven counties comprising its Region and continues to monitor the use of the network within those counties. From time to time the Commission retains consultants to develop processes and/or mathematical formulas to assist surveyors, public works engineers, and other users in the use of the networks. However, some county land information system managers continue to request that the Commission investigate the means by which the legacy networks could be converted to newer datums and to estimate the attendant costs.

This appendix proposes new methods for converting the Commission legacy horizontal datum, from NAD 27 to the latest newer datum and adjustment—the North American Datum of 1983 with the National Adjustment of 2011, (NAD 83 (2011)), and for converting the legacy vertical datum from the NGVD 29 to the North American Vertical Datum of 1988 adjustment of 2012, (NAVD 88 (2012)), and to do so cost effectively.

METHODOLOGY FOR CONVERSION OF HORIZONTAL CONTROL

The Commission staff has developed a method for the conversion of its legacy horizontal control survey coordinate positions to the new horizontal datum while maintaining the relative positions of the legacy control survey stations, and maintaining the original accuracy standards of the network. The method utilizes the measurements made in the creation of the legacy horizontal control survey network within the Region and minimizes the number of field observations required to position the control survey stations on the new datum and on the corresponding map projection. As already noted, the legacy network utilizes monumented corners of the USPLSS as control survey stations and, in effect, recreates the USPLSS within the Region tying that system to the National geodetic control system.

The datum conversion method developed by the Commission staff can be applied by subareas of the Region as small as six square miles in extent, although more practical subareas would consist of USPLSS townships, or of entire counties. When applied at the township level, the method requires field observations to obtain the coordinate positions of the township corners on the new datum together with such observations on a carefully selected number of control survey stations—approximately eight—consisting of section and quarter-section corners within the township. Four of the eight corners could be the four corners marking the exterior boundaries of a six-section SEWRPC Control Survey Summary Diagram (CSSD) used by the Commission to display the legacy control survey network. Having determined the coordinate positions on the new datum of approximately 12 USPLSS corners—the coordinates of the remaining 157 corners are computed using the lengths of the quarter-section lines and the interior angles of the quarter sections within the township as determined in the legacy survey. This computation consists of a least squares adjustment[1] of the network within the township.

Upon completion of the determination of the coordinate positions of all of the stations—USPLSS corners—within the area concerned, a small random sample of stations would be selected and the coordinate positions of these stations determined by additional field observations, thus providing a check on the accuracy of the completed conversion. If discrepancies exceeding the desired accuracy standards are found appropriate adjustments or further field measurements would have to be made.

The method developed by the Commission staff significantly reduces the cost entailed in datum conversion from such costs entailed in application of the conversion method proposed in SEWRPC Technical Report No. 206. Importantly, the method preserves the integrity of the legacy control survey network within the Region, maintaining the relative positions in the form of quarter-section-line lengths and bearings as determined in the creation of the legacy network, and does so within the accuracy standards of that network.

Field Observations

As noted, the conversion method requires the conduct of a limited number of field observations to determine the coordinate positions on the new datum of a carefully selected number of existing legacy stations. The necessary field observations would be made using state-of-the-art GPS instrumentation and procedures.

The Wisconsin Department of Transportation (WisDOT) completed a network of Continuous Operating Reference Stations (WISCORS) within the Region and the State in 2015. These stations within and adjacent to the Region are shown on Figure 1, and serve as the primary control network within the Region, replacing the old First- and Second-Order triangulation and base line stations. Satellite measurements permit the creation of a mathematical model that supports an online processing technology known as Virtual Reference Station (VRS) technology. This technology permits real-time positioning without the need for base stations and with minimal observation times while achieving centimeter-level accuracy. The VRS[2] technology is proposed to serve as the basis of the field measurements needed to determine horizontal positions in the new datum.

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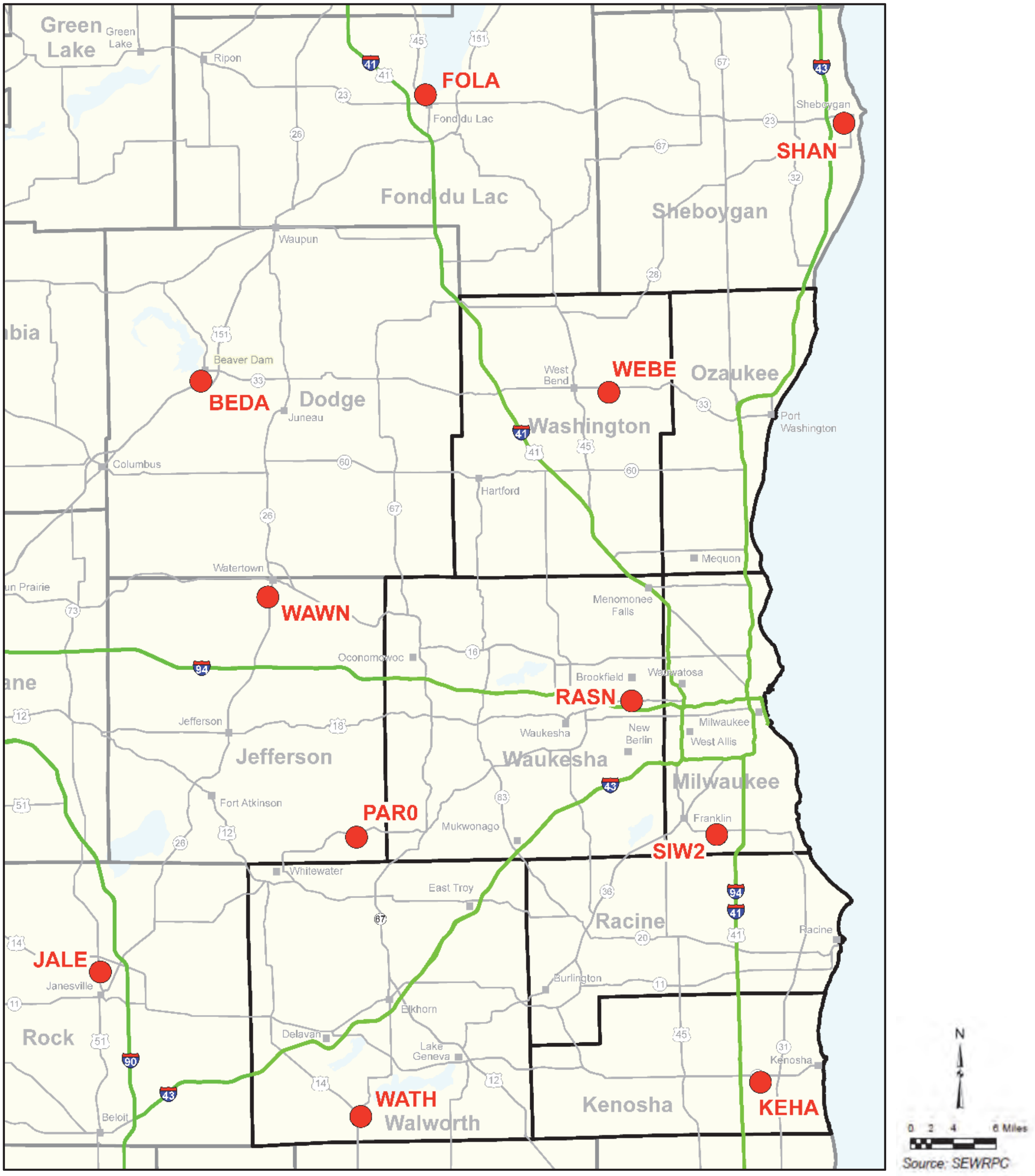
[1]*The term "least squares adjustment" refers to a mathematical procedure based on the theory of probability that derives the statistically most likely coordinate location of points defined by multiple measurements in a network. Moreover, a least squares adjustment defines a best-fit solution for weighed measurements finding a minimum for the sum of the squares of the measurement residuals. A measurement residual is the amount needed to correct a measurement for it to fit into the best-fit solution found by the least squares adjustment.*

[2]*For definition of VRS technology see Footnote 2, page 2, of Addendum.*

Figure 1

WISCORS STATIONS IN AND ADJACENT TO THE SOUTHEASTERN WISCONSIN REGION



The following protocol would be followed in making the necessary field observations:

1. For each of the control survey stations—USPLSS corners—to be occupied, a copy of the SEWRPC "Record of U.S. Public Land Survey Control Station" (dossier sheet) shall be obtained.

2. The dossier sheet shall be used to recover the station, and a minimum of two of the tie distances from the station to witness marks shown on the dossier sheets shall be measured to ensure that the station has not been disturbed.

3. The following potential sources of error shall be considered and adjusted for in the measurement process: positional dilution of precision (PDOP), number of satellites visible, mask angle, potential multipath, and solar activity.

4. Each observation shall have a minimum duration of 5 seconds using a 1-second epoch rate.

5. At the end of the observation, the antenna of the instrument shall be set near the ground so a complete loss of satellite lock occurs. The antenna shall then be repositioned over the monument for an additional observation.

6. A minimum of three observations shall be made at each station occupied. The second and third direct observation shall also have at a minimum a duration of 5 seconds using a 1-second epoch rate.

7. Steps 5 and 6 shall be repeated as necessary to obtain the desired minimum of three observations.

8. The Root Mean Square Error (RMSE) of the three observations shall be calculated for each coordinate component (Northing, Easting, and Elevation) at each of the stations occupied using the following equation.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}[Average_i - Check_i]^2}{N}}$$

   $Average_i$ = Average position of the Northing, Easting, or Elevation at the USPLSS Corner

   $Check_i$ = Northing, Easting, or Elevation value from the individual GPS observations at a USPLSS Corner

   N = Number of observations at a USPLSS corner

9. The computed RMSE for the Northing, Easting, and Elevation components shall not exceed the following:

   Northing 0.06 foot
   Easting 0.06 foot
   Elevation 0.09 foot

10. Additional observations shall be performed as required to meet the maximum allowable RMSE. Any combination of observations may be used to achieve the acceptable RMSE, provided all coordinate components (Northing, Easting, and Elevation) are used in the solution.

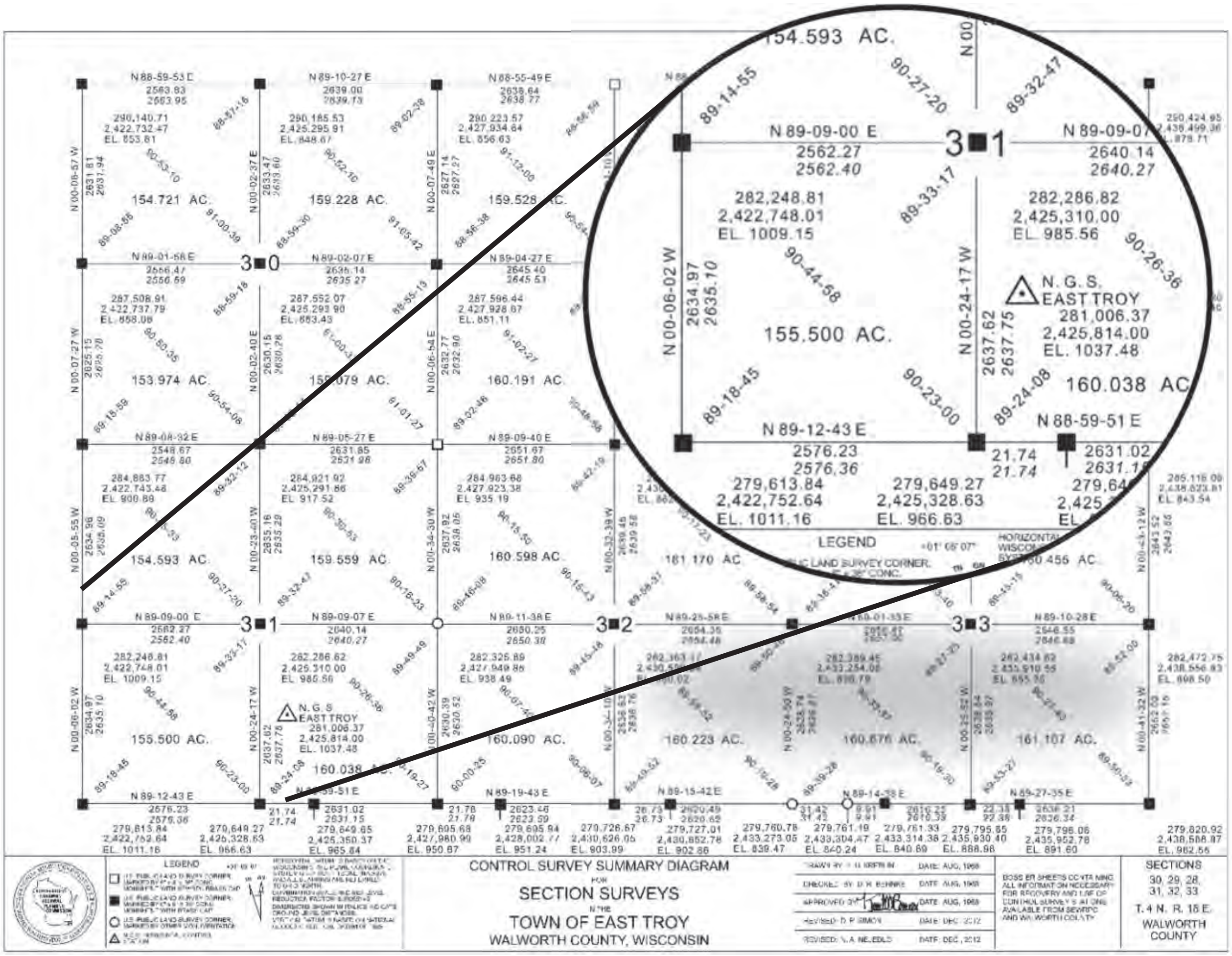
Computations

Two major computation phases are involved in the proposed horizontal datum conversion methodology. The first phase consists of the extraction of legacy system information. The second phase consists of a least squares adjustment converting the legacy positions to the new datum.

The use of legacy system information is considered the most significant feature of the proposed methodology. The use of this information will not only serve to reduce costs, but will assist in validating the control station positioning, and serve to identify any issues that might arise in the conversion process such as not achieving the desired accuracy standards in a part of the network.

Figure 2

TYPICAL SEWRPC CONTROL SURVEY SUMMARY DIAGRAM



Source: SEWRPC.

The information from the legacy system required is found on CSSD. The first and most important piece of such information consists of the published grid distance between stations – USPLSS Corners. Also required are the interior angles between quarter-section lines. The angles will be extracted so that at corners of the quarter sections the interior angles are read clockwise. Figure 2 provides an example of a CSSD, and of the information that will be extracted for use in a least squares adjustment of the network.

Using the station – corner – identification system that is described in the next section (See Figure 3), Table 1 illustrates the format of the values to be extracted from CSSD to be used in the least squares adjustments.

Once the legacy spatial measurements have been extracted from the CSSDs, the second phase of the computations—the least squares adjustment—can be carried out. The complexity entailed in the management of compilations relating a control survey network consisting of almost 12,000 stations makes a single adjustment impractical. It is therefore, proposed to break the conversion compilations into manageable segments consisting of subareas of the Region. As already noted, these areas could be as small as six square miles, or as large as a county. A survey township would constitute a particularly practical subarea. Individual adjustments would be performed working serially so adjacent subarea boundary corners can be constrained to fit from previous adjustments.

Table 1

FORMAT OF INPUT TO LEAST SQUARE ADJUSTMENT

Code (A: Angle)	Backsight – At – Foresight	Angle (Degrees – Minutes – Seconds)
A	0418144-0418169-0418168	89-18-45
A	0418145-0418144-0418169	90-44-58
A	0418168-0418145-0418144	89-33-17
A	0418169-0418168-0418145	90-23-00
A	0418145-0418168-0318012	89-24-08
Code (D: Distance)	From - To	Grid Distance (US Survey Feet)
D	0418144-0418169	2634.97
D	0418144-0418145	2562.27
D	0418169-0418168	2576.23
D	0418145-0418168	2637.62
D	0418168-0318012	21.74

Source: SEWRPC.

The first step in the least squares computation is to constrain the legacy control positions. This provides verification of the accuracy of the legacy control survey network as documented by each CSSD and the completeness of the input of the spatial measurements. After acceptance of the CSSD spatial measurements, additional CSSDs can be added to the network until the defined adjustment area has been completed.

Once the individual areas have been completed in this manner, a final step prior to incorporating the new positional data is the application of an effective weighting strategy. This is critical given the use of legacy measurements integrating with the precise GPS field observed positioning. An effective strategy will allow displacement of the differences (measurement residuals) found between the measurement types, and account for the numerous possible measurement paths between unconstrained USPLSS corners. The algorithms in a least squares adjustment provide a rigorous means for this. Tolerance and weights could change once the network design is applied to the entire subarea concerned. However, a typical half mile length, the weight assigned for the grid distance would be 0.03 foot and interior angle at 30 arc seconds. USPLSS corner positions (new datum positons) that have been observed but not constrained in the network adjustment would be assigned weights of 0.1 foot (both Northing and Easting).

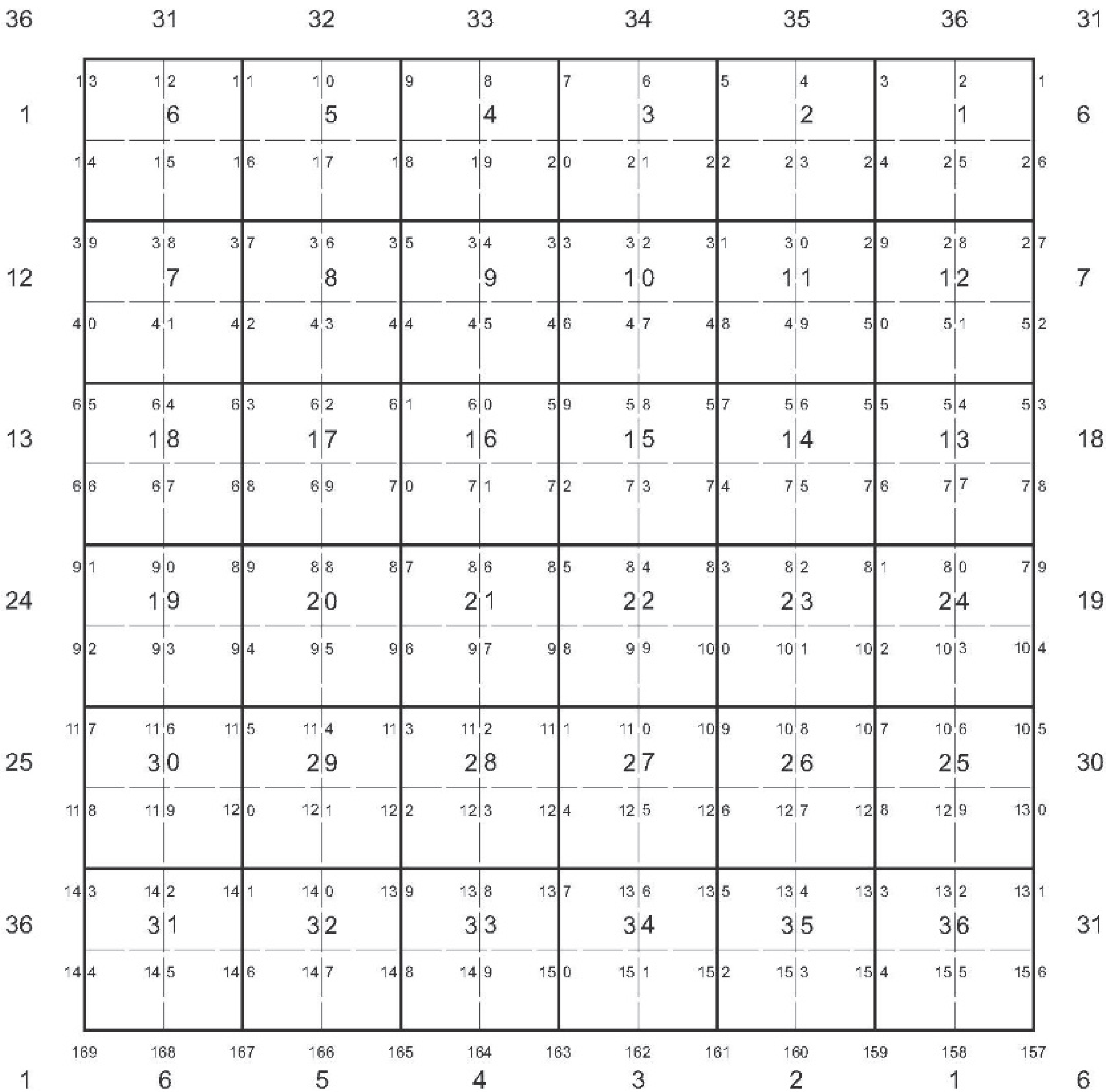
CONTROL SURVEY STATION NUMBERING

A control survey station numbering system will be required that provides a unique numeric identification for each control survey station in the network throughout the Region. This will allow stations to be used in multiple adjustments without conflict or duplication in the control networks. It is proposed to use the Commission’s long-standing numbering system for this purpose. That system is illustrated in Figure 3.

Under the Commission system, the number identifying each station, while unique within each township, it is not unique for corners located along common range lines between two townships, or for common corners along township lines. The Commission system would be modified by adding a prefix to each corner number specifying the township and range. Corners along the eastern and southern boundaries of every township would be numbered

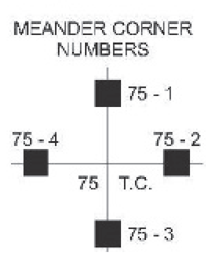
Figure 3

PROPOSED CONTROL SURVEY STATION – USPLSS CORNER – NUMBERING SYSTEM



T ________ N , R ________ E

U.S.P.L.S. SECTION AND QUARTER SECTION CORNERS WHICH HAVE BEEN RELOCATED, MONUMENTED, AND COORDINATED



NOTE: IF NUMBER IS RULED OUT, SEE ABUTTING TOWN FOR DOSSIER.

PREPARED BY: SEWRPC.

Source: SEWRPC.

according to the normal township numbering system. However, corners along the northern and western boundaries would be numbered using the numbers of the corners in the adjacent township. This provides a unique number for every corner and eliminates the possibility of corners having two numbers as would be the case if numbered by individual township. The northern boundaries of townships containing closing corners would be numbered as followed by the Commission system aside from the added town and range prefix.

DEMONSTRATION APPLICATION OF METHODOLOGY

A demonstration application of the horizontal datum conversion methodology developed by the Commission staff was carried out in July 2015. A typical 6-square-mile area consisting of Sections 28 through 33 in Township 4 North, Range 18 East, Town of East Troy, Walworth County, was selected for the demonstration.

The legacy data for the demonstration area are shown on Figure 4. The monuments marking four corners of the area, together with the monument marking the Southwest corner of Section 29 which is near the center of the area, were occupied and the coordinate positions of these corners on NAD 83 (2011) were determined by a GPS survey. The survey was conducted in accordance with the protocol set forth in this appendix. The newly determined coordinate positions for these five corners are shown on Figure 5.

The ground level lengths of the quarter-section lines within the area, together with the interior angles of the quarter sections, were extracted from the legacy data shown on the diagram comprising Figure 4. The ground level lengths of the quarter-section lines were reduced to grid lengths using the combination elevation and scale reduction factor for the State Plane Coordinate System based upon the new datum. A least square adjustment of the network was then used to compute the State Plane Coordinates[3] of the remaining 30 stations—corners—within the area. The resulting values are shown on the diagram comprising Figure 5. The grid distances and bearings of the one-quarter section lines on the new datum were then determined by inverse computation from the new coordinate values. The grid distances were then converted to ground level distances using the combination factor for the new coordinate system. The areas of the quarter-sections were computed using the new ground level distances and bearings of the quarter-section lines. These results are also shown on the diagram comprising Figure 5.

Examination of the two diagrams comprising Figures 4 and 5 will show that the maximum change in the ground level length of the quarter-section lines between the legacy and new datums was 0.13 foot. The maximum change in the bearings of the quarter-section lines was 7 seconds of arc. The maximum change in the computed areas of the one-quarter sections was 0.011 acre.

Seven of the computed USPLSS corners were selected for an independent performance evaluation. These corners are identified on the diagram comprising the Figure 5. The monuments marking these corners were occupied and the coordinate position of these corners on the new datum determined by GPS survey. A comparison of the computed and the surveyed values is provided in Table 2. The maximum difference in the coordinate values of 0.23 foot falls well within the desired accuracy standard specified for the legacy network within the Region.

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[3]*The NAD 83 state plane coordinate values are defined in meters. For this appendix the metric values were converted to feet using the ratio of 39.37 inches per meter exact to 12 inches per U.S. Survey Foot, which approximates 1 meter equaling 3.280833333 U.S. Survey Feet.*

Table 2

NAD83/2011 COMPUTED POSITIONS VERSUS GPS OBSERVED INDEPENDENT POSITIONS

	Computed		GPS Observed (July 23, 2015)		Delta (USFT)	
USPLSS Corner	Northing (USFT)	Easting (USFT)	Northing (USFT)	Easting (USFT)	Northing	Easting
0418123	287,734.64	2,404,333.97	287,734.73	2,404,333.98	0.09	0.01
0418150	282,482.37	2,407,019.81	282,482.60	2,407,019.82	0.23	0.01
0418167	279,705.08	2,396,443.96	279,705.12	2,396,443.88	-0.04	0.08
			GPS Observed (March 5, 2015)			
0418115	290,233.03	2,396,397.43	290,233.00	2,396,397.53	-0.03	0.10
0418116	290,194.98	2,393,758.74	290,194.87	2,393,758.84	-0.11	0.10
			GPS Observed (February 9, 2015)			
0417130	287,518.28	2,391,200.65	287,518.24	2,391,200.67	-0.04	0.02
0418131	284,893.05	2,391,206.35	284,893.08	2,391,206.29	0.03	-0.06
				Average:	0.03	0.01
				Maximum Difference:	0.23	0.10
				Minimum Difference:	-0.11	-0.08
				Standard Deviation:	0.11	0.07

Source: SEWRPC.

METHODOLOGY FOR CONVERSION OF VERTICAL CONTROL

The foregoing text deals only with the datum conversion relating to horizontal positions. As noted in the addendum to which this appendix is attached, a similar problem exists relating to the vertical control survey network within the Region. The elevation data provided by the legacy vertical control survey network are based upon the NGVD 29. The National Geodetic Survey in 1977, began a new adjustment project that became the new vertical datum, the North American Vertical Datum of 1988 (NAVD 88). As is the case for horizontal positions, no precise mathematical relationship exists between the legacy and new datums. The Commission in 1995, published SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin.* That report provided a means for converting elevations from the legacy datum to the new datum and provided an iso-hypsometric map to facilitate the conversion of orthometric heights and elevations from one datum to the other. The iso-hypsometric map provided in SEWRPC Technical Report No. 35 was based on the interpolation of datum differences computed for points located on a 10,000-foot grid using VERTCON. The validity of VERTCON was checked by using the datum differences at the 435 NGS (former U.S. Coast and Geodetic Survey) bench marks within the Region as published by NGS.

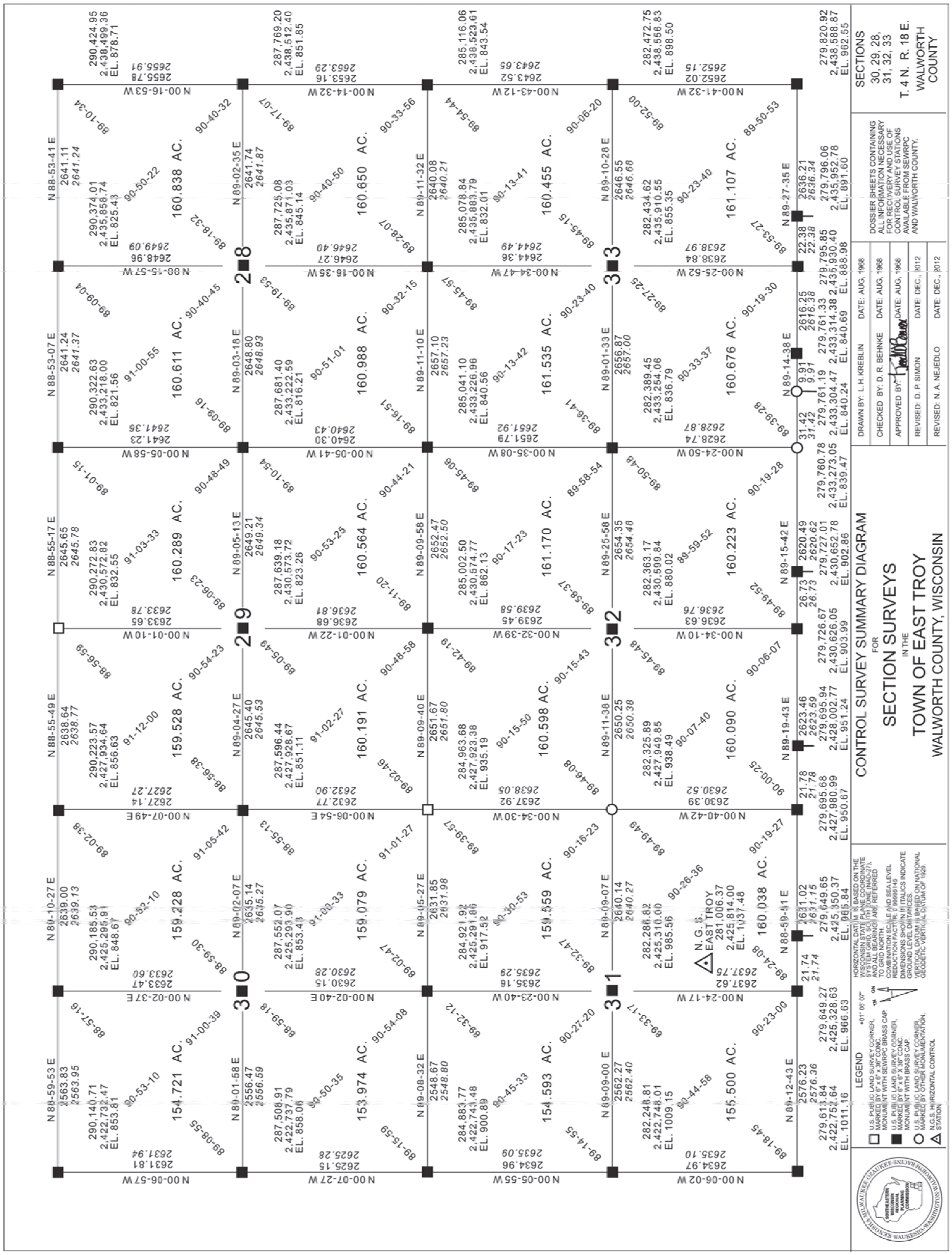
Since the completion of SEWRPC Technical Report No. 35, the Wisconsin Department of Transportation (WisDOT) in conjunction with NGS completed the Wisconsin Height Modernization Program (WI-HMP) within the Region. This program provided high-order orthometric height data on a carefully distributed network of substantial monumented bench marks. The locations of these bench marks are shown on Figure 6. The orthometric heights determined for these bench marks are referred to NAVD 88 (2012).

It is proposed to effect the conversion of elevations between the legacy and new datum by establishing accurate, measured legacy datum elevations on each of the 460 height modernization stations within the Region, thus, establishing an accurate, measured relationship between the two datums on each of the stations. The legacy datum elevations would be established by differential level surveys connecting the Commission legacy bench marks to the height modernization stations. Such transfer should involve no more than the survey of approximately one-half mile of high-order differential level lines for each transfer.

Using the accurate differences between the two datums as determined by actual differential level survey for each datum, a new iso-hypsometric map of the Region can be prepared. This map may be expected to be more accurate than the map provided in SEWRPC Technical Report No. 35. This map can then be used to transfer orthometric heights and elevations between the two datums to Second-Order, Class II accuracy standards.

Figure 4

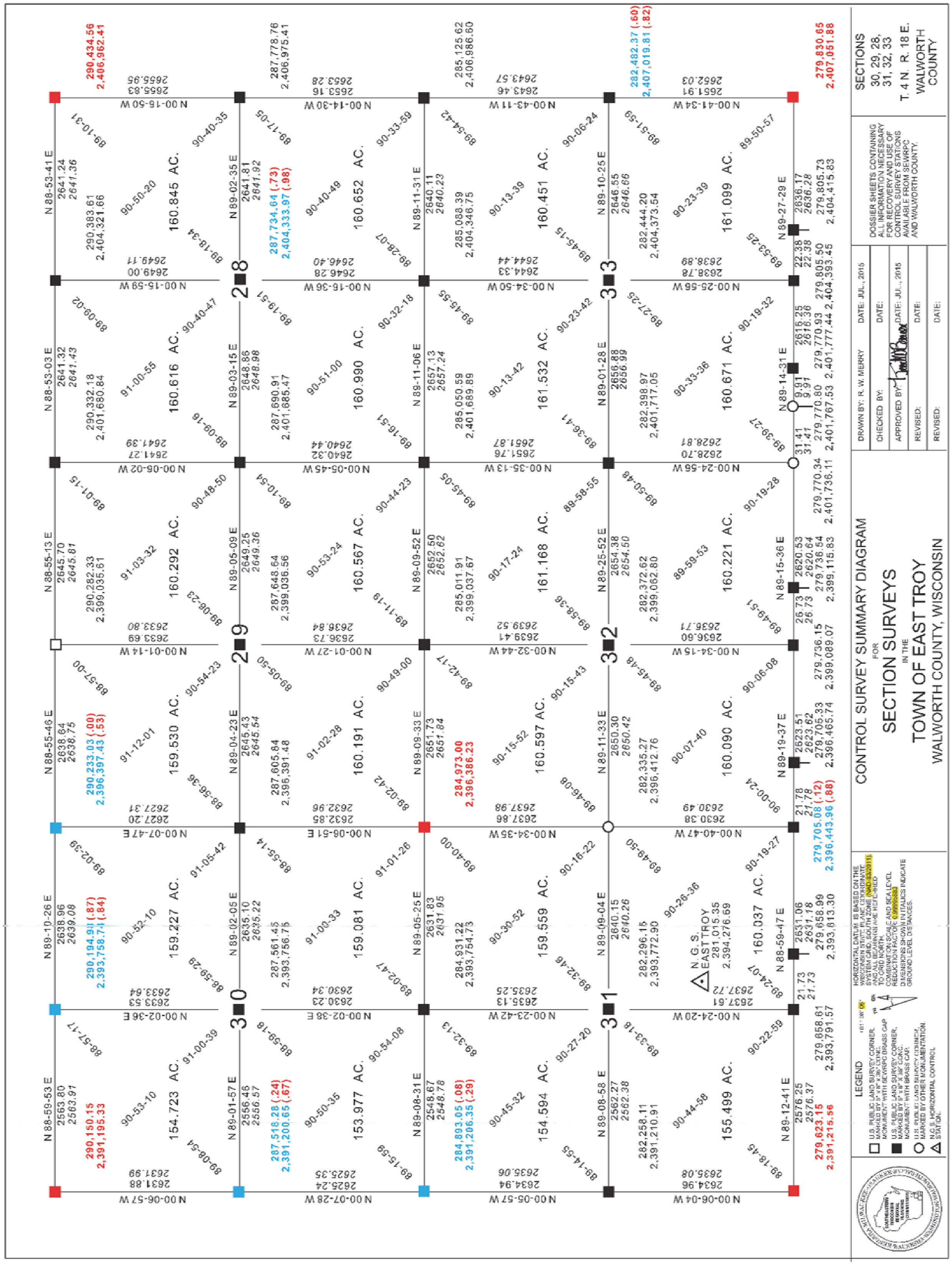
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 27



Source: SEWRPC.

Figure 5

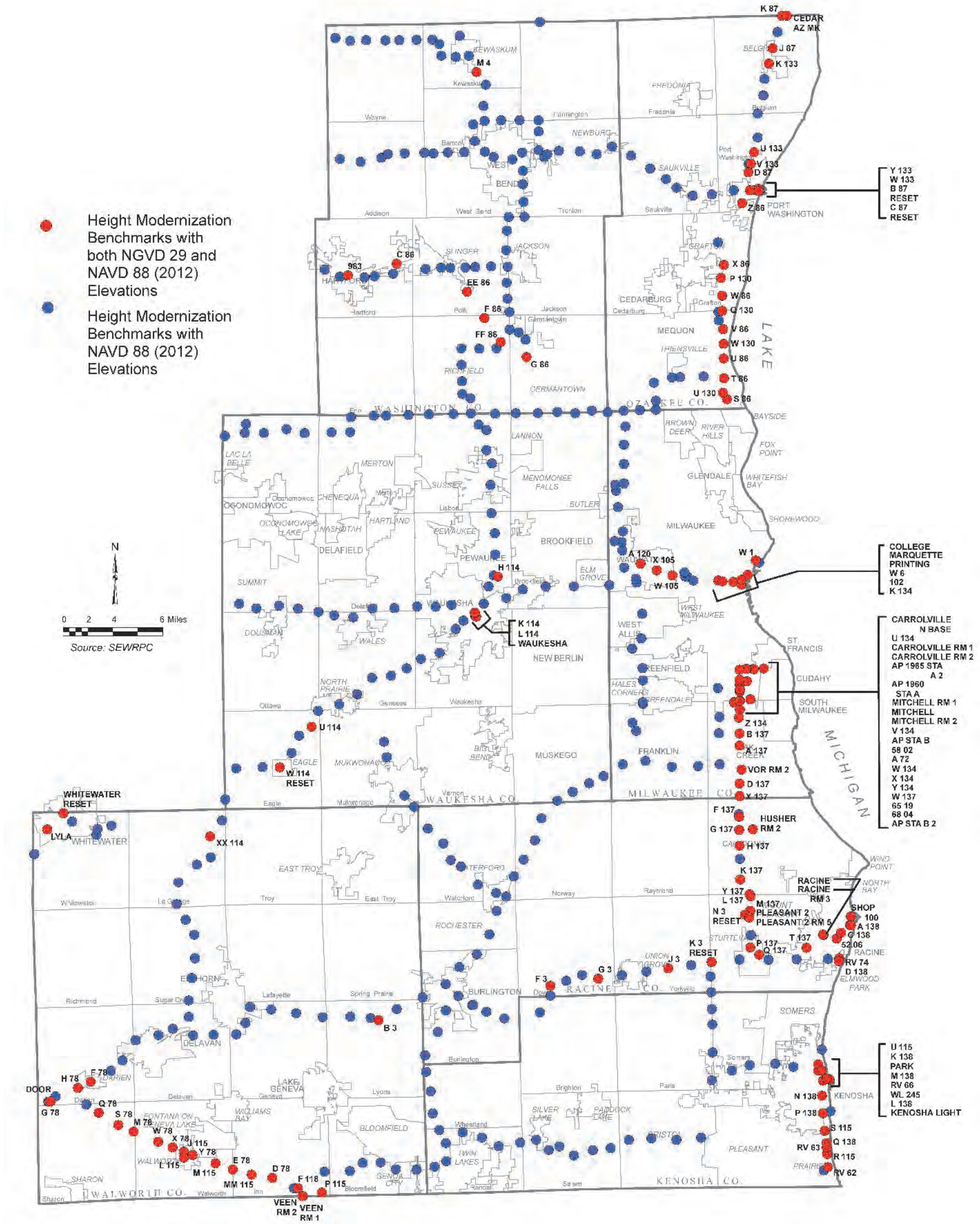
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 83 (2011)



Source: SEWRPC.

Figure 6

WISCONSIN HEIGHT MODERNIZATION BENCH MARKS WITHIN THE SOUTHEASTERN WISCONSIN REGION



Source: SEWRPC.

REVISED "RECORD OF USPLSS CONTROL STATION" DOCUMENTS

The Commission has prepared and maintains a document known as "Record of U.S. Public Land Survey Control Station" for each of the more than 11,000 control survey stations – USPLSS corners within, and in a few cases, adjacent to the Region. These documents are commonly referred to as "dossier" sheets. As a control survey station is converted from the legacy to the new datums, a new dossier sheet will have to be provided. A revised format will be required for the dossier sheets and a proposed format is provided in Figure 7. The proposed format provides for the display of dual horizontal positions and vertical heights of the station.

Figure 7

REVISED "RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION"

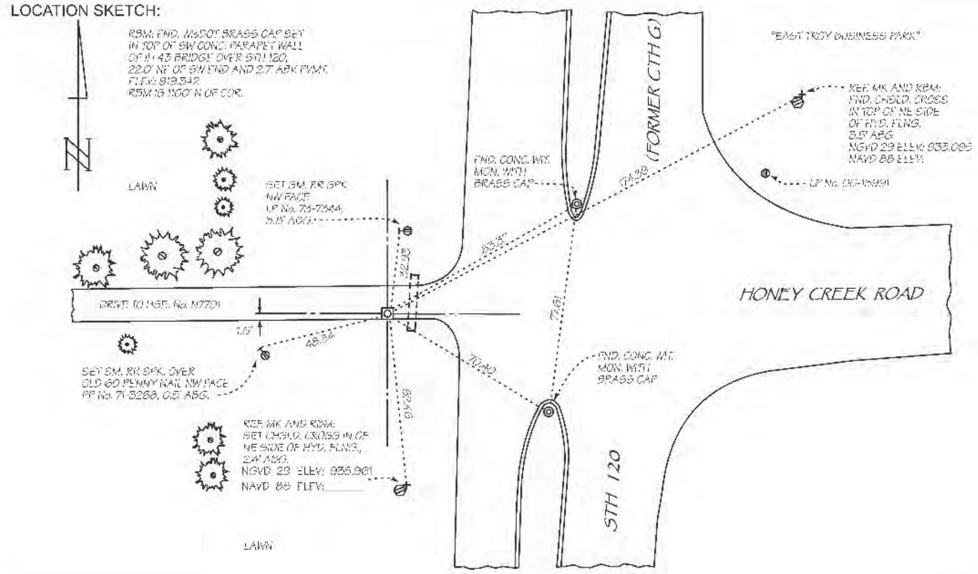
RECORD OF U. S. PUBLIC LAND SURVEY CONTROL STATION

U. S. PUBLIC LAND SURVEY CORNER 30|29 31|32 T 4 N, R 18 E, WALWORTH COUNTY, WISCONSIN

HORIZONTAL CONTROL SURVEY BY: SEWRPC	YEAR: 2001	HORIZONTAL CONTROL SURVEY BY: SEWRPC	YEAR: 2015
VERTICAL CONTROL SURVEY BY: OWEN AYRES / SEWRPC	YEAR: 2002/2012	VERTICAL CONTROL SURVEY BY: SEWRPC	YEAR: 2015

HORIOZNTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1927	HORIOZNTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (2011)
VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929	VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (2012)
STATE PLANE COORDINATES OF:	STATE PLANE COORDINATES OF:
NORTHING: 284,963.68 USFT	NORTHING: 284,973.00 USFT
EASTING: 2,427,923.38 USFT	EASTING: 2,396,386.23 USFT
ELEVATION: 935.187 FT	ELEVATION:
HORIZONTAL ACCURACY: THIRD ORDER, CLASS I	HORIZONTAL ACCURACY: THIRD ORDER, CLASS I (GPS OBSERVED)
VERTICAL ACCURACY: SECOND ORDER, CLASS II	VERTICAL ACCURACY: SECOND ORDER, CLASS II (INTERPOLATED)

LOCATION SKETCH:



SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN)
WALWORTH COUNTY) SS

As Walworth County Surveyor, I hereby certify that following water main construction, I set a concrete monument with SEWRPC brass cap to mark the location of this corner; replacing a concrete monument with Walworth County brass cap set to mark the location of this corner in September 1985 by Lloyd L. Jensen, S-211, former Walworth County Surveyor; replacing a cast iron plug with cross set in the then existing bituminous driveway pavement in October 1961 by George A. Swier, State Highway Commission of Wisconsin Project Engineer, following highway reconstruction; 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.

DATE OF SURVEY: 23 JULY 2007 ______________ REGISTERED LAND SURVEYOR S - 157

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FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Source: SEWRPC.

COSTS

The costs of the various major work elements involved in datum conversion were estimated separately for the horizontal and vertical components of the work entailed. The costs were developed by analyzing the major work elements of each of the two conversions.

For the horizontal datum conversion, six major work elements were considered:

1. The extraction of the data required from the legacy control survey network. These data include the location and monumentation of existing control survey stations—USPLSS corners; the lengths of the quarter-section lines; the interior angles of the quarter-sections; and attendant combination scale and sea level reduction factors.
2. The necessary field observations including the recovery of a set of carefully located and distributed legacy control survey stations and the conduct of the GPS observations on these stations as required to determine the coordinates of the stations concerned referred to NAD 83 (2011).
3. The determination of the coordinate positions of all of the other stations in the network concerned utilizing the data extracted from the legacy network.
4. Selection of an approximately 10 percent sample of the stations having computed coordinates for occupation and GPS survey to check the coordinate values of the selected stations.
5. Preparation of new "Record of U.S. Public Land Survey Control Station" document—dossier sheet—for each of the control survey stations concerned.
6. Preparation and publication of a project completion report.

For each of these major work elements, estimates were made of the direct and indirect labor costs, of the associated overhead costs, and an allowance for contingencies. These costs are set forth in Table 3. The costs of such items as mileage, equipment, and report preparation would need to estimated on a job-by-job basis, assuming that the Commission performs the work entailed. Estimates were made of the cost of implementation of the horizontal datum conversion for the seven-county Region as a whole; and for implementation by subarea—namely by survey township. These costs are presented in Tables 3 through 5. In any consideration of these costs estimates, it should be recognized that precise estimates, of the costs of completion of the work by a specific county, or by specific subarea, are possible only on the basis of a more detailed study design for the conduct of the work by the area concerned. Consequently, the costs of the work elements set forth in the Tables 3 through 5 must be considered tentative and changes in the allocation of costs to work elements must be expected as the work proceeds. It should be noted that if the datum conversion is implemented by subarea, the cost of completing a larger area, such as a county or the Region, as a whole, will be somewhat higher.

The costs of the work would have to be borne by those individual county land information systems that desire the horizontal datum conversion to be completed. Work could be accomplished for the county as a whole or by subareas, particularly survey townships. The estimated cost by county is provided in Table 4 and by typical township in Table 5.

For the vertical datum conversion, four major work elements were considered:

1. The high-order differential level circuits required to determine accurate elevations referred to NGVD 29 for each of the 460 Height Modernization stations within the Region. The total length of the level lines was estimated at approximately 250 miles.
2. The computation of the surveyed vertical datum differences at each of the 460 height modernization stations.
3. Preparation of a new iso-hypsometric map of the Region by interpolation of the datum differences found at the 460 height modernization stations.
4. Preparation and publication of a project completion report.

Table 3

COST ESTIMATE – HORIZONTAL DATUM CONVERSION - SEVEN COUNTY REGION

Description	Cost
Extraction of Legacy Measurements	$49,600
Field Observations	
• Labor	179,520
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	19,680
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	33,000
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	118,400
Total	$400,200[a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

Table 4

COST ESTIMATE – HORIZONTAL DATUM CONVERSION – INDIVIDUAL COUNTY

Description	Cost						
	Kenosha County	Milwaukee County	Ozaukee County	Racine County	Walworth County	Washington County	Waukesha County
Extraction of Legacy Measurements	$5,080	$4,400	$4,400	$6,360	$10,520	$7,960	$10,880
Field Observations • Labor	18,240	16,200	15,960	23,040	38,400	28,800	38,880
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	1,920	1,500	1,800	2,520	3,840	3,240	4,860
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	3,520	2,640	3,520	4,400	7,040	4,400	7,480
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	12,136	10,656	10,360	14,800	25,456	19,240	25,752
Individual County Total	$40,896 [a]	$35,396 [a]	$36,040 [a]	$51,120 [a]	$85,256 [a]	$63,640 [a]	$87,852 [a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

For each of these major work elements, estimates of the costs were made in the same manner as for the horizontal datum conversion work.

As a practical matter, the work entailed in vertical datum conversion should be completed for the Region as a whole. These costs are presented in Table 6. The costs of the work would have to be borne by the individual county land information systems. The costs could be distributed among the counties on the basis of any system agreed to by the seven-county land information systems. One such possible system would utilize the proportional area that each county comprises of the Region. The application of this system is illustrated in Table 7.

Table 5

COST ESTIMATE - HORIZONTAL DATUM CONVERSION - TYPICAL TOWNSHIP

Description	Cost
Extraction of Legacy Measurements	$ 960
Field Observations • Labor	3,600
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	720
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	880
Preparation of new “Record of U.S. Public Land Survey Control Station” documents and Control Survey Summary Diagrams	1,480
Total	$7,640[a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

Table 6

COST ESTIMATE – VERTICAL DATUM CONVERSION - SEVEN COUNTY REGION

Description	Cost Breakdown
High Order Differential Level Circuits to Determine Accurate NGVD 29 Elevations on 460 Height Modernization Bench Marks within Region	$177,408
Compilation and Computations Supporting the Vertical Differences of the Height Modernization Bench Marks	26,400
Preparation of new Iso-Hypsometric Map	8,800
Preparation and Publication of Project Completion Report	13,200
Preparation of new “Record of U.S. Public Land Survey Control Station” documents and Control Survey Summary Diagrams	76,960
Total	$302,768

Source: SEWRPC.

Table 7

COST ESTIMATE - VERTICAL DATUM CONVERSION - INDIVIDUAL COUNTY

Description	Percent of Regional Area	Cost
Kenosha County	10.3	$31,185
Milwaukee County	9.0	27,249
Ozaukee County	8.8	26,644
Racine County	12.7	38,452
Walworth County	21.4	64,792
Washington County	16.2	49,048
Waukesha County	21.6	65,398
Total	100.0	$302,768

Source: SEWRPC.