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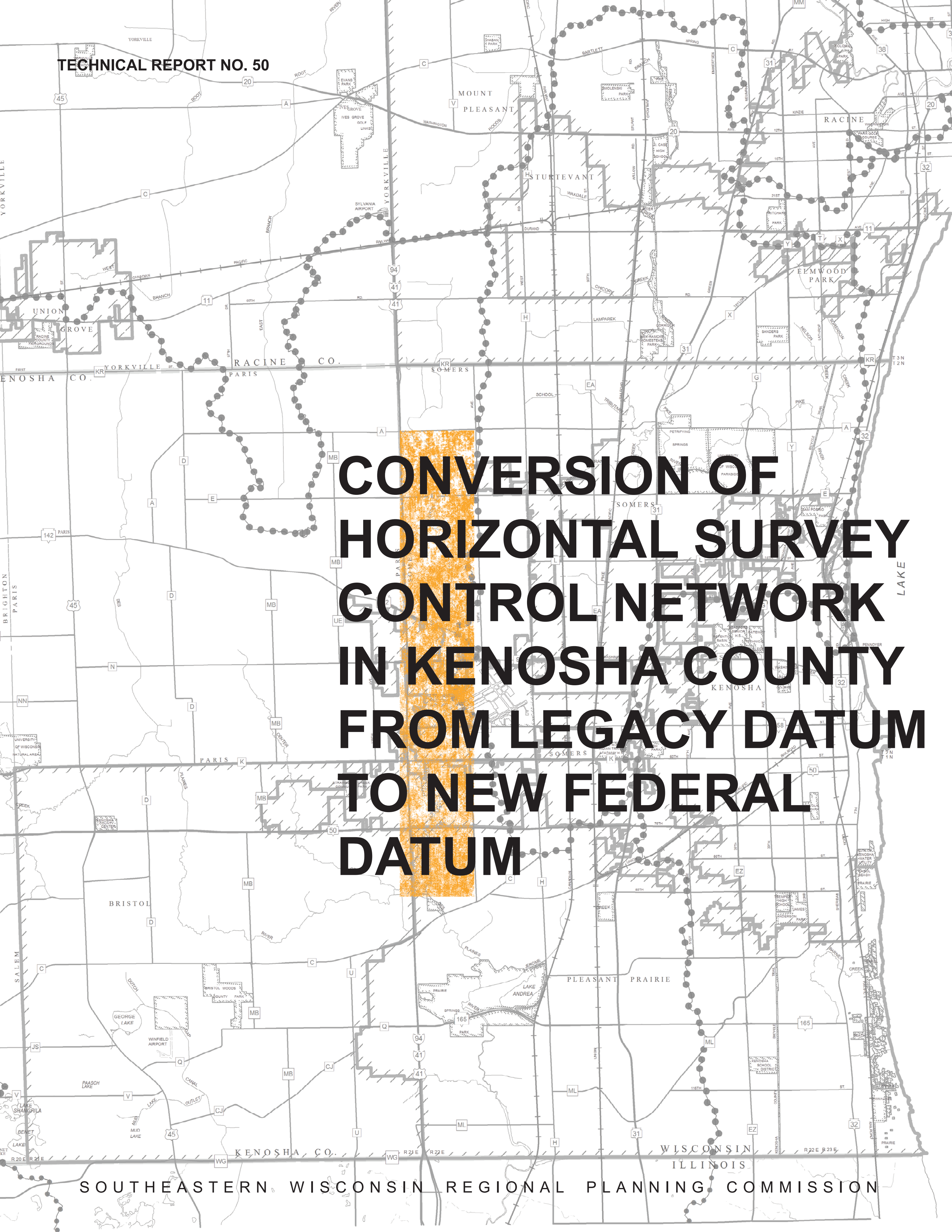

CONVERSION OF HORIZONTAL SURVEY CONTROL NETWORK IN KENOSHA COUNTY FROM LEGACY DATUM TO NEW FEDERAL DATUM

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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 August 25, 2016, the Commission entered into an agreement with Kenosha 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 early 1964, the Regional Planning Commission has recommended to the governmental agencies operating within the Southeastern Wisconsin Region the use of a unique system of survey control as a basis for the compilation of large-scale topographic and cadastral maps; as a basis for the conduct of land and engineering surveys; and, since 1985, as a basis for the development of automated, parcel-based, land information and public works management systems within the Region. The recommended survey control system 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 certain ancillary benchmarks have been referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929), a datum formerly known as the Sea Level Data 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 adjusted 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 do 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 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.” 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."

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 high orders of accuracy in control survey work. The originally proposed conversion procedure utilized a series of static Global Positioning System (GPS) observations[1] to provide new primary and secondary survey control networks within the Region. Based upon these 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.[2] This technology eliminates: 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.

[1] *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.*

[2] *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 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 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 results of 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 by far, 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 August 25, 2016, Kenosha County entered into an agreement with the Commission under which the Commission would convert the State Plane Coordinate positions of all 1,136 U.S. Public Land Survey System 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. A copy of Appendix C of the Addendum to Memorandum Report No. 206 is provided in Appendix A 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 Appendix C, 135 remonumented U.S. Public Land Survey System 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.[3] During the observations, the GPS receiver was connected 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 feet steel tapes required to measure tie distances to witness corners, and to make attendant miscellaneous angular and distance measurements.

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[3] *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 Kenosha 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 were corrected.

The second step in the computation process involved combining the measured NAD (2011) coordinate positions with the legacy lengths of the one-quarter section lines and the interior angles of the one-quarter sections in a least squares adjustment to compute the NAD 83 (2011) coordinate positions of the 1,001 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.

Careful analyses of the results of the computations indicated that six of the survey control stations—U.S. Public Land Survey System corners—did not, with respect to the lengths of the quarter section lines concerned, set the surrounding adjacent stations within the desired accuracy. The discrepancies range from a low of 0.3 ft. to a high of 1.10 ft. These six stations are shown on Figure 2 appended, and the discrepancies found for these stations are given in Table 2 appended. Investigation of the history of the monumentation marking these stations as given by the dossier sheets on record for these stations indicated that the discrepancies found for five of the six stations concerned were caused by a lack of adequate care in positioning the extant replacement monument with respect to the location of the monument replaced and the true position of the station. For one of the six stations concerned, the discrepancy was attributed to the movement of the monument by soil slippage of the steeply sloped embankment in which the monument was set. Commission experience indicates that great care must be exercised in setting a replacement monument so that it is in the same position as the monument being replaced, any differences in positioning being limited to no more than 0.05 ft. Accordingly, the County Surveyor will move each of the six monuments concerned to the originally determined location of the corner. The NAD 83 (2011) coordinates assigned to these six stations as given by the control summary diagrams delivered to the county under this project are the coordinates of the true location of these corners.

FIELD VERIFICATION OF COMPUTED CORNER POSITIONS

To check the accuracy of the computed survey control station coordinates, an approximately 15 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 157 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 3. Review of the data presented in Table 3 indicates that the largest difference between a measured and a computed northing was 0.20 of a foot, while the largest difference between a measured and a computed easting was also 0.20 of a foot. The average of the differences between the measured and computed northings was 0.01 of a foot, and of the eastings also 0.01 of a foot. 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 0.081 seconds of latitude, and 0.275 seconds of longitude, equivalent to about eight feet and 27 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 extent horizontal survey control network within Kenosha 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 1,136 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 50 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

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
1	249259.14	2455729.09
2	249347.53	2460909.14
3	249403.36	2463498.29
4	249582.07	2471373.96
5	249733.48	2476625.94
6	250111.63	2487290.61
7	250229.27	2492339.02
8	250318.18	2497767.92
9	250407.10	2502998.58
10	250593.38	2510926.03
11	250661.16	2513619.83
12	250728.82	2516254.74
13	250823.28	2521426.61
14	250855.90	2524085.40
15	250888.41	2526744.27
16	250912.12	2529383.49
17	250934.03	2532055.48
18	250960.70	2534429.30
19	250988.69	2539744.85
20	250966.11	2550504.78
21	251085.32	2555787.04
22	248513.88	2557387.46
23	245726.67	2553265.75
24	245766.81	2542572.46
25	245686.52	2526598.41
26	245387.68	2511122.73
27	245000.86	2492462.32
28	244557.07	2471529.51
29	241610.15	2463704.60
30	238713.14	2455957.91
31	239472.22	2479621.89
32	240018.44	2503233.58
33	240157.90	2519222.71
34	240371.82	2534766.03
35	240356.63	2550750.48

Corner Number	Northing	Easting
36	240522.53	2555541.42
37	237067.47	2492738.67
38	235114.25	2463849.53
39	234090.21	2477119.39
40	234817.25	2514049.42
41	235149.85	2542878.53
42	232097.15	2508843.23
43	227444.26	2429831.95
44	227674.89	2440377.21
45	228160.68	2456222.13
46	228664.38	2471957.12
47	229015.40	2487924.90
48	229376.14	2503623.52
49	229577.32	2519548.11
50	229762.56	2535055.27
51	229810.63	2548380.83
52	229879.20	2553716.77
53	226908.10	2516960.46
54	221972.51	2424633.71
55	222707.05	2451069.00
56	223103.27	2464223.89
57	223569.21	2480097.28
58	223844.46	2493253.64
59	224422.52	2529851.16
60	224489.94	2540504.48
61	224596.31	2553855.35
62	222040.29	2555772.92
63	221683.99	2522006.10
64	216780.49	2427346.70
65	217082.18	2437960.37
66	217611.19	2456487.14
67	218047.85	2472373.13
68	218261.81	2480270.88
69	218404.50	2485572.55
70	218761.85	2504019.68

Table 1 (continued)

Corner Number	Northing	Easting
71	218851.70	2509279.27
72	218971.24	2517202.65
73	219156.63	2535385.18
74	219210.67	2551362.11
75	219423.34	2556661.22
76	213877.01	2554266.17
77	213741.05	2543628.99
78	213782.05	2538324.36
79	213621.04	2527724.03
80	213457.99	2514780.17
81	213264.45	2496268.27
82	212973.00	2480512.82
83	212579.68	2464677.72
84	212083.12	2451350.59
85	211694.66	2438152.74
86	210771.84	2512242.89
87	208521.64	2551856.23
88	208461.38	2538546.06
89	208044.64	2507055.75
90	207841.08	2488595.67
91	207470.46	2472749.70
92	206818.55	2451500.47
93	206405.71	2438304.98
94	204612.57	2425158.63
95	204557.36	2462316.46
96	204761.71	2470197.45
97	205635.01	2520382.59
98	203226.78	2554779.77
99	203160.32	2544102.13
100	203140.72	2538794.51
101	203033.54	2530905.25
102	202690.54	2496671.41
103	201720.79	2456924.27

Corner Number	Northing	Easting
104	201060.51	2435800.14
105	198540.27	2441165.71
106	198780.31	2449079.90
107	199754.32	2480939.50
108	200247.43	2515303.26
109	197774.25	2533793.34
110	197449.93	2504826.52
111	197241.82	2486309.35
112	196904.87	2473065.68
113	195633.02	2428066.16
114	193258.01	2441328.50
115	195056.65	2520800.31
116	195212.59	2547177.23
117	195326.90	2558628.35
118	192524.49	2544659.46
119	192440.61	2531416.13
120	192244.11	2510266.67
121	192052.56	2491743.12
122	191334.47	2462622.81
123	190829.76	2449350.81
124	187739.90	2430945.52
125	188982.55	2473294.45
126	189312.74	2486535.97
127	187904.07	2560825.95
128	187264.32	2552919.48
129	187187.32	2539642.50
130	187102.41	2521091.05
131	186878.17	2505164.67
132	186192.07	2468077.13
133	185926.92	2460136.13
134	185318.91	2441608.28
135	184952.44	2425732.98

CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 1.

Source: SEWRPC.

Table 2

MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS THE COORDINATES OF WHICH WERE FOUND TO DISAGREE WITH LEGACY MEASUREMENTS COORDINATES GIVEN ARE REFERRED TO NAD 83 (2011)

Corner Number		Northing	Easting
1	Computed	251149.53	2558013.76
	GPS Observed	251150.11	2558013.55
	Difference	-0.58	0.21
2	Computed	232543.68	2554869.04
	GPS Observed	232543.79	2554868.00
	Difference	-0.11	1.04
3	Computed	221808.37	2535302.12
	GPS Observed	221809.47	2535302.22
	Difference	-1.10	-0.10

Corner Number		Northing	Easting
4	Computed	195314.42	2557831.14
	GPS Observed	195314.77	2557831.62
	Difference	-0.35	-0.48
5	Computed	192670.73	2557961.12
	GPS Observed	192671.01	2557961.32
	Difference	-0.28	-0.20
6	Computed	192621.45	2555302.77
	GPS Observed	192621.93	2555302.95
	Difference	-0.48	-0.18

CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 3.

Source: SEWRPC.

Table 3

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

Corner Number		Northing	Easting
1	Computed	249348.120	2460936.380
	GPS Observed	249347.973	2460936.501
	Difference	0.147	-0.121
2	Computed	249461.150	2466195.960
	GPS Observed	249460.961	2466195.761
	Difference	0.189	0.199
3	Computed	250032.550	2484624.980
	GPS Observed	250032.474	2484624.891
	Difference	0.076	0.089
4	Computed	250660.300	2513585.530
	GPS Observed	250660.311	2513585.494
	Difference	-0.011	0.036
5	Computed	250728.380	2516237.530
	GPS Observed	250728.365	2516237.533
	Difference	0.015	-0.003
6	Computed	250820.330	2521149.420
	GPS Observed	250820.346	2521149.489
	Difference	-0.016	-0.069
7	Computed	250851.940	2523762.650
	GPS Observed	250851.948	2523762.728
	Difference	-0.008	-0.078
8	Computed	250884.410	2526417.020
	GPS Observed	250884.404	2526416.994
	Difference	0.006	0.026
9	Computed	250909.140	2529051.430
	GPS Observed	250909.198	2529051.441
	Difference	-0.0580	-0.011
10	Computed	251027.890	2553138.500
	GPS Observed	251027.887	2553138.485
	Difference	0.003	0.015
11	Computed	251161.190	2558418.200
	GPS Observed	251161.237	2558418.398
	Difference	-0.047	-0.198

Corner Number		Northing	Easting
12	Computed	248463.280	2555828.640
	GPS Observed	248463.221	2555828.568
	Difference	0.059	0.072
13	Computed	248382.720	2539835.510
	GPS Observed	248382.788	2539835.319
	Difference	-0.068	0.191
14	Computed	247500.720	2484707.060
	GPS Observed	247500.698	2484707.042
	Difference	0.022	0.018
15	Computed	247202.670	2471431.730
	GPS Observed	247202.658	2471431.718
	Difference	0.012	0.012
16	Computed	246618.820	2455782.520
	GPS Observed	246618.833	2455782.353
	Difference	-0.012	0.167
17	Computed	244192.330	2461027.500
	GPS Observed	244192.307	2461027.348
	Difference	0.023	0.152
18	Computed	244332.650	2466266.460
	GPS Observed	244332.532	2466266.363
	Difference	0.118	0.097
19	Computed	244662.830	2476822.510
	GPS Observed	244662.862	2476822.472
	Difference	-0.032	0.038
20	Computed	245315.350	2503132.580
	GPS Observed	245315.384	2503132.622
	Difference	-0.034	-0.042
21	Computed	245459.310	2519061.050
	GPS Observed	245459.356	2519061.232
	Difference	-0.046	-0.182
22	Computed	245733.800	2529253.660
	GPS Observed	245733.784	2529253.613
	Difference	0.016	0.047

Table 3 (continued)

Corner Number		Northing	Easting
23	Computed	245825.290	2555903.610
	GPS Observed	245825.162	2555903.621
	Difference	0.128	-0.011
24	Computed	245857.200	2556844.920
	GPS Observed	245857.240	2556844.992
	Difference	-0.040	-0.072
25	Computed	243065.730	2529328.840
	GPS Observed	243065.731	2529328.810
	Difference	-0.001	0.030
26	Computed	242221.360	2487516.300
	GPS Observed	242221.318	2487516.434
	Difference	0.042	-0.134
27	Computed	242202.410	2484848.730
	GPS Observed	242202.293	2484848.826
	Difference	0.117	-0.096
28	Computed	241359.010	2455898.570
	GPS Observed	241358.917	2455898.514
	Difference	0.093	0.056
29	Computed	238956.130	2463762.100
	GPS Observed	238956.225	2463762.024
	Difference	-0.095	0.076
30	Computed	239376.470	2476976.170
	GPS Observed	239376.439	2476976.300
	Difference	0.031	-0.130
31	Computed	239709.990	2492641.840
	GPS Observed	239709.960	2492641.798
	Difference	0.030	0.042
32	Computed	240049.450	2508543.960
	GPS Observed	240049.382	2508543.842
	Difference	0.068	0.118
33	Computed	240113.820	2513905.650
	GPS Observed	240113.864	2513905.672
	Difference	-0.044	-0.022
34	Computed	240341.690	2524104.720
	GPS Observed	240341.548	2524104.724
	Difference	0.142	-0.004

Corner Number		Northing	Easting
35	Computed	240432.980	2540094.480
	GPS Observed	240432.900	2540094.351
	Difference	0.080	0.129
36	Computed	240471.840	2545385.910
	GPS Observed	240471.811	2545386.044
	Difference	0.029	-0.134
37	Computed	237769.770	2548150.960
	GPS Observed	237769.708	2548151.079
	Difference	0.062	-0.119
38	Computed	236932.890	2487686.800
	GPS Observed	236932.969	2487686.849
	Difference	-0.079	-0.049
39	Computed	236078.110	2456023.540
	GPS Observed	236078.167	2456023.414
	Difference	-0.057	0.126
40	Computed	233436.170	2456095.580
	GPS Observed	233436.177	2456095.540
	Difference	-0.007	0.040
41	Computed	234424.160	2492848.930
	GPS Observed	234424.283	2492848.865
	Difference	-0.123	0.065
42	Computed	234651.490	2500745.520
	GPS Observed	234651.433	2500745.476
	Difference	0.057	0.044
43	Computed	234863.460	2519388.090
	GPS Observed	234863.469	2519388.168
	Difference	-0.009	-0.078
44	Computed	235069.430	2529539.440
	GPS Observed	235069.440	2529539.366
	Difference	-0.010	0.0740
45	Computed	235071.090	2534912.850
	GPS Observed	235070.944	2534912.961
	Difference	0.146	-0.111
46	Computed	235108.740	2540219.870
	GPS Observed	235108.863	2540219.802
	Difference	-0.123	0.068

Table 3 (continued)

Corner Number		Northing	Easting
47	Computed	232503.520	2553652.490
	GPS Observed	232503.387	2553652.485
	Difference	0.133	0.005
48	Computed	232512.910	2545594.800
	GPS Observed	232512.970	2545594.896
	Difference	-0.060	-0.096
49	Computed	231987.990	2500844.400
	GPS Observed	231987.949	2500844.443
	Difference	0.041	-0.043
50	Computed	231527.240	2479855.070
	GPS Observed	231527.281	2479855.020
	Difference	-0.041	0.050
51	Computed	230802.170	2456158.830
	GPS Observed	230802.115	2456158.713
	Difference	0.055	0.117
52	Computed	227828.550	2445646.050
	GPS Observed	227828.585	2445646.136
	Difference	-0.035	-0.086
53	Computed	228216.750	2457727.790
	GPS Observed	228216.652	2457727.775
	Difference	0.098	0.015
54	Computed	228317.480	2461420.960
	GPS Observed	228317.315	2461420.846
	Difference	0.165	0.114
55	Computed	228381.110	2464050.100
	GPS Observed	228380.959	2464050.036
	Difference	0.151	0.064
56	Computed	228558.220	2469326.200
	GPS Observed	228558.220	2469326.166
	Difference	0.000	0.034
57	Computed	228798.810	2477277.890
	GPS Observed	228798.852	2477277.908
	Difference	-0.042	-0.018
58	Computed	228875.920	2479930.560
	GPS Observed	228875.918	2479930.588
	Difference	0.002	-0.028

Corner Number		Northing	Easting
59	Computed	228994.390	2485256.600
	GPS Observed	228994.307	2485256.646
	Difference	0.083	-0.046
60	Computed	229136.680	2493037.060
	GPS Observed	229136.835	2493037.081
	Difference	-0.155	-0.021
61	Computed	229554.490	2516888.030
	GPS Observed	229554.478	2516887.929
	Difference	0.012	0.101
62	Computed	229728.400	2529726.930
	GPS Observed	229728.422	2529726.880
	Difference	-0.022	0.050
63	Computed	229825.890	2543025.270
	GPS Observed	229825.756	2543025.248
	Difference	0.134	0.022
64	Computed	227189.150	2545770.150
	GPS Observed	227189.008	2545770.199
	Difference	0.142	-0.049
65	Computed	227123.700	2537782.820
	GPS Observed	227123.868	2537782.633
	Difference	-0.168	0.187
66	Computed	226936.650	2519620.560
	GPS Observed	226936.598	2519620.518
	Difference	0.052	0.042
67	Computed	226877.410	2514320.500
	GPS Observed	226877.433	2514320.524
	Difference	-0.023	-0.024
68	Computed	226785.740	2509019.960
	GPS Observed	226785.781	2509019.978
	Difference	-0.041	-0.018
69	Computed	226295.740	2482665.030
	GPS Observed	226295.854	2482664.985
	Difference	-0.114	0.045
70	Computed	225745.500	2464140.330
	GPS Observed	225745.428	2464140.264
	Difference	0.072	0.066

Table 3 (continued)

Corner Number		Northing	Easting
71	Computed	224931.600	2435170.460
	GPS Observed	224931.560	2435170.330
	Difference	0.040	0.130
72	Computed	222167.130	2429931.100
	GPS Observed	222167.252	2429930.963
	Difference	-0.122	0.137
73	Computed	223638.910	2482758.350
	GPS Observed	223639.009	2482758.275
	Difference	-0.099	0.075
74	Computed	223743.210	2488068.820
	GPS Observed	223743.211	2488068.744
	Difference	-0.001	0.076
75	Computed	224021.830	2501159.330
	GPS Observed	224021.871	2501159.275
	Difference	-0.041	0.055
76	Computed	224135.980	2509109.770
	GPS Observed	224136.022	2509109.782
	Difference	-0.042	-0.012
77	Computed	224260.510	2517052.480
	GPS Observed	224260.514	2517052.522
	Difference	-0.004	-0.042
78	Computed	223151.820	2556540.130
	GPS Observed	223151.862	2556540.196
	Difference	-0.042	-0.066
79	Computed	221923.950	2553949.130
	GPS Observed	221923.878	2553949.160
	Difference	0.072	-0.030
80	Computed	221852.280	2543268.410
	GPS Observed	221852.437	2543268.480
	Difference	-0.157	-0.070
81	Computed	221750.350	2527325.420
	GPS Observed	221750.350	2527325.449
	Difference	0.00	-0.029
82	Computed	220845.180	2477537.600
	GPS Observed	220845.230	2477537.691
	Difference	-0.050	-0.091

Corner Number		Northing	Easting
83	Computed	220786.570	2474883.570
	GPS Observed	220786.647	2474883.765
	Difference	-0.077	-0.195
84	Computed	220623.330	2469597.260
	GPS Observed	220623.414	2469597.445
	Difference	-0.084	-0.185
85	Computed	220460.010	2464297.610
	GPS Observed	220460.066	2464297.688
	Difference	-0.056	-0.078
86	Computed	220377.290	2461664.060
	GPS Observed	220377.368	2461664.110
	Difference	-0.078	-0.050
87	Computed	220310.120	2459015.820
	GPS Observed	220310.316	2459015.794
	Difference	-0.196	0.026
88	Computed	220063.460	2451128.390
	GPS Observed	220063.518	2451128.543
	Difference	-0.058	-0.153
89	Computed	219854.380	2443192.880
	GPS Observed	219854.250	2443192.726
	Difference	0.130	0.154
90	Computed	219654.360	2435261.750
	GPS Observed	219654.269	2435261.631
	Difference	0.091	0.119000
91	Computed	219509.510	2429967.780
	GPS Observed	219509.518	2429967.959
	Difference	-0.008	-0.179
92	Computed	217798.620	2464364.640
	GPS Observed	217798.613	2464364.634
	Difference	0.007	0.006
93	Computed	218562.040	2493416.210
	GPS Observed	218561.955	2493416.264
	Difference	0.085	-0.054
94	Computed	218652.750	2498734.160
	GPS Observed	218652.739	2498734.123
	Difference	0.011	0.037

Table 3 (continued)

Corner Number		Northing	Easting
95	Computed	219065.860	2524772.420
	GPS Observed	219065.830	2524772.351
	Difference	0.030	0.069
96	Computed	219115.990	2530104.400
	GPS Observed	219115.920	2530104.327
	Difference	0.070	0.073
97	Computed	216462.070	2546170.950
	GPS Observed	216462.014	2546170.961
	Difference	0.056000	-0.011
98	Computed	214463.770	2443330.960
	GPS Observed	214463.699	2443330.766
	Difference	0.071	0.194
99	Computed	212396.200	2459382.720
	GPS Observed	212396.035	2459382.888
	Difference	0.165	-0.168
100	Computed	212690.790	2469986.150
	GPS Observed	212690.939	2469986.336
	Difference	-0.149	-0.186
101	Computed	212829.030	2475228.870
	GPS Observed	212829.209	2475228.984
	Difference	-0.179	-0.114
102	Computed	213125.460	2488415.490
	GPS Observed	213125.522	2488415.509
	Difference	-0.062	-0.019
103	Computed	213324.030	2506859.450
	GPS Observed	213324.184	2506859.341
	Difference	-0.154	0.109
104	Computed	213399.180	2509486.830
	GPS Observed	213399.268	2509486.786
	Difference	-0.088	0.044
105	Computed	213503.070	2517423.490
	GPS Observed	213503.056	2517423.386
	Difference	0.0140	0.104
106	Computed	213611.020	2525075.980
	GPS Observed	213611.015	2525076.080
	Difference	0.005	-0.100
107	Computed	213909.670	2557789.530
	GPS Observed	213909.704	2557789.566
	Difference	-0.034	-0.036
108	Computed	211165.770	2546368.580
	GPS Observed	211165.738	2546368.725
	Difference	0.032	-0.145
109	Computed	210672.960	2499023.110
	GPS Observed	210672.949	2499023.027
	Difference	0.011	0.083
110	Computed	209845.820	2462140.530
	GPS Observed	209845.715	2462140.354
	Difference	0.105	0.176
111	Computed	209363.190	2448752.840
	GPS Observed	209363.124	2448752.747
	Difference	0.066	0.093
112	Computed	209168.710	2443506.450
	GPS Observed	209168.538	2443506.458
	Difference	0.172	-0.008
113	Computed	208839.590	2427657.100
	GPS Observed	208839.778	2427657.298
	Difference	-0.188	-0.198
114	Computed	208310.090	2525303.650
	GPS Observed	208310.095	2525303.459
	Difference	-0.005	0.191
115	Computed	208327.320	2530648.530
	GPS Observed	208327.288	2530648.464
	Difference	0.032	0.066
116	Computed	205897.250	2554650.660
	GPS Observed	205897.424	2554650.787
	Difference	-0.174	-0.127
117	Computed	205855.440	2546660.940
	GPS Observed	205855.475	2546660.967
	Difference	-0.035	-0.027
118	Computed	205403.540	2507164.840
	GPS Observed	205403.504	2507164.902
	Difference	0.036	-0.062

Table 3 (continued)

Corner Number		Northing	Easting
119	Computed	205362.130	2499221.690
	GPS Observed	205362.028	2499221.649
	Difference	0.102	0.041
120	Computed	205299.100	2493914.030
	GPS Observed	205298.954	2493914.082
	Difference	0.146	-0.052
121	Computed	205134.080	2483416.530
	GPS Observed	205134.008	2483416.563
	Difference	0.0720	-0.033
122	Computed	204896.270	2475491.240
	GPS Observed	204896.459	2475491.085
	Difference	-0.189	0.155
123	Computed	204699.900	2467568.220
	GPS Observed	204699.903	2467568.209
	Difference	-0.003	0.011
124	Computed	203765.870	2438387.650
	GPS Observed	203765.803	2438387.632
	Difference	0.067	0.0180
125	Computed	201026.440	2430534.390
	GPS Observed	201026.367	2430534.533
	Difference	0.073	-0.143
126	Computed	202766.260	2507273.780
	GPS Observed	202766.232	2507273.834
	Difference	0.028	-0.054
127	Computed	202849.550	2512572.730
	GPS Observed	202849.650	2512572.772
	Difference	-0.100	-0.042
128	Computed	203140.490	2541448.940
	GPS Observed	203140.606	2541448.951
	Difference	-0.116	-0.011
129	Computed	199955.910	2491463.410
	GPS Observed	199955.955	2491463.386
	Difference	-0.045	0.024
130	Computed	199882.630	2486215.500
	GPS Observed	199882.710	2486215.301
	Difference	-0.080	0.199

Corner Number		Northing	Easting
131	Computed	199413.270	2467735.730
	GPS Observed	199413.127	2467735.638
	Difference	0.143	0.092
132	Computed	199248.940	2462444.620
	GPS Observed	199248.891	2462444.647
	Difference	0.049	-0.027
133	Computed	198697.790	2446434.210
	GPS Observed	198697.758	2446434.111
	Difference	0.032	0.099
134	Computed	195723.280	2433339.540
	GPS Observed	195723.281	2433339.566
	Difference	-0.001	-0.026
135	Computed	197535.380	2510116.730
	GPS Observed	197535.356	2510116.784
	Difference	0.024	-0.054
136	Computed	197743.810	2531180.220
	GPS Observed	197743.760	2531180.127
	Difference	0.050	0.093
137	Computed	197804.800	2536369.890
	GPS Observed	197804.837	2536369.955
	Difference	-0.037	-0.065
138	Computed	194452.530	2481089.850
	GPS Observed	194452.428	2481089.781
	Difference	0.102	0.069
139	Computed	194334.730	2475792.980
	GPS Observed	194334.778	2475793.004
	Difference	-0.048	-0.024
140	Computed	193973.470	2462565.320
	GPS Observed	193973.458	2462565.198
	Difference	0.012	0.122
141	Computed	193490.570	2449263.300
	GPS Observed	193490.489	2449263.296
	Difference	0.081	0.004
142	Computed	192980.720	2428119.510
	GPS Observed	192980.914	2428119.444
	Difference	-0.194	0.066

Table 3 (continued)

Corner Number		Northing	Easting
143	Computed	190681.970	2444063.910
	GPS Observed	190682.155	2444063.850
	Difference	-0.185	0.060
144	Computed	191024.760	2454661.360
	GPS Observed	191024.789	2454661.420
	Difference	-0.029	-0.060
145	Computed	191957.770	2486464.210
	GPS Observed	191957.775	2486464.313
	Difference	-0.005	-0.103
146	Computed	192306.900	2515596.670
	GPS Observed	192306.767	2515596.776
	Difference	0.133	-0.106
147	Computed	192499.990	2539339.200
	GPS Observed	192499.813	2539339.312
	Difference	0.177	-0.112
148	Computed	192700.550	2559432.760
	GPS Observed	192700.528	2559432.573
	Difference	0.022	0.187
149	Computed	189986.770	2558079.950
	GPS Observed	189986.845	2558080.035
	Difference	-0.075	-0.085
150	Computed	189879.510	2547469.790
	GPS Observed	189879.636	2547469.794
	Difference	-0.126	-0.004

Corner Number		Northing	Easting
151	Computed	189763.560	2526222.650
	GPS Observed	189763.440	2526222.753
	Difference	0.120	-0.103
152	Computed	189359.940	2499782.950
	GPS Observed	189359.779	2499782.987
	Difference	0.161	-0.037
153	Computed	188845.600	2468008.300
	GPS Observed	188845.670	2468008.341
	Difference	-0.070	-0.041
154	Computed	187670.260	2428290.710
	GPS Observed	187670.405	2428290.661
	Difference	-0.145	0.049
155	Computed	186517.110	2430987.630
	GPS Observed	186517.123	2430987.451
	Difference	-0.013	0.179
156	Computed	185549.680	2449553.760
	GPS Observed	185549.604	2449553.887
	Difference	0.076	-0.127
157	Computed	186970.800	2513128.800
	GPS Observed	186970.704	2513128.680
	Difference	0.096	0.120

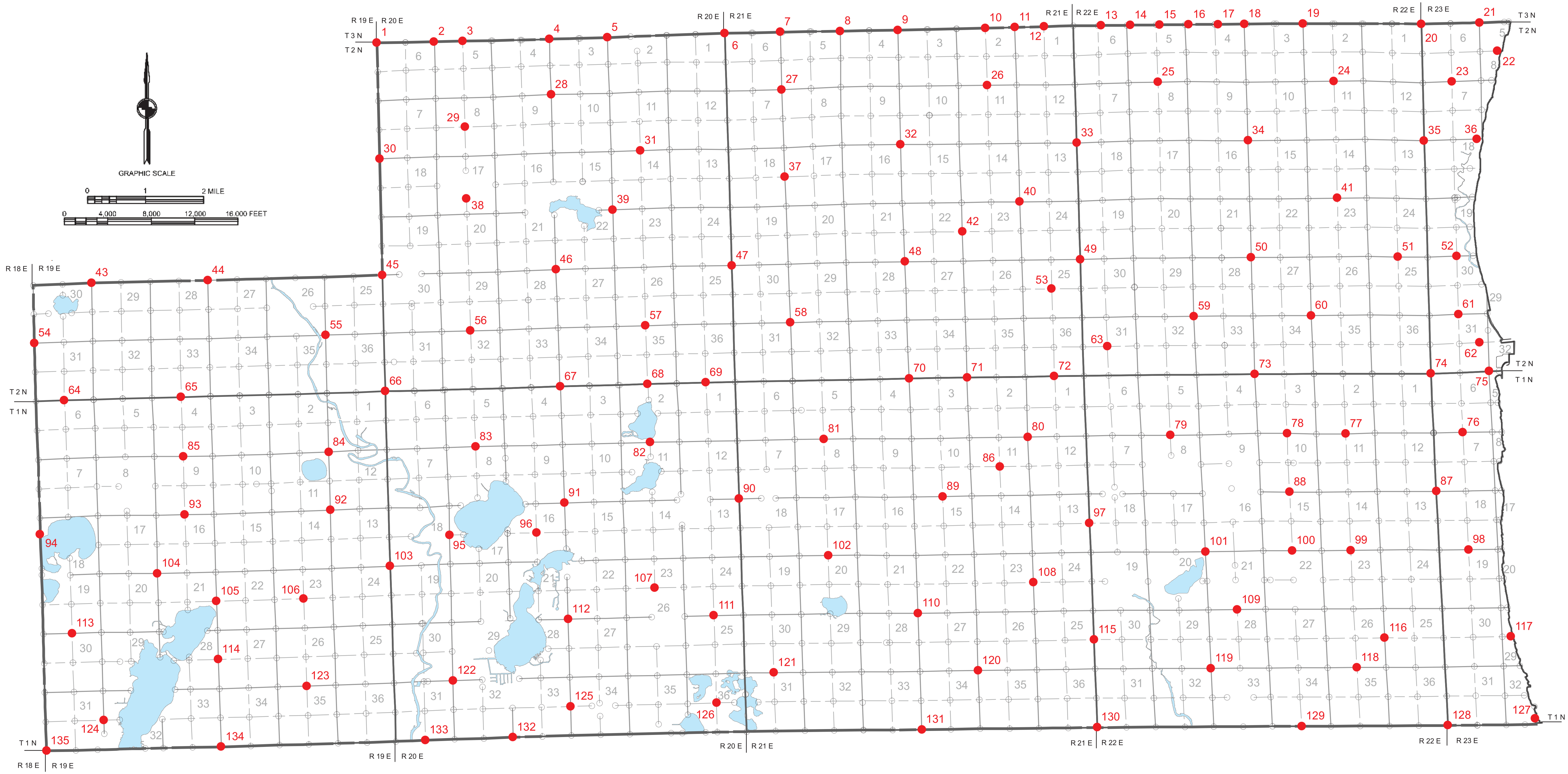
CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 2

	Northing	Easting
Sum of Squared Differences	1.260	1.447
Average	0.004	0.004
Minimum Difference...	-0.196	-0.198
Maximum Difference..	0.189	0.199
RMSE	0.090	0.096
$RMSE_{min}$ / $RMSE_{max}$	0.930	
NSSDA 95% RMSE $Accuracy_{r}$	0.227	
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 KENOSHA COUNTY SHOWING U.S. PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO DETERMINE NAD 83 (2011)

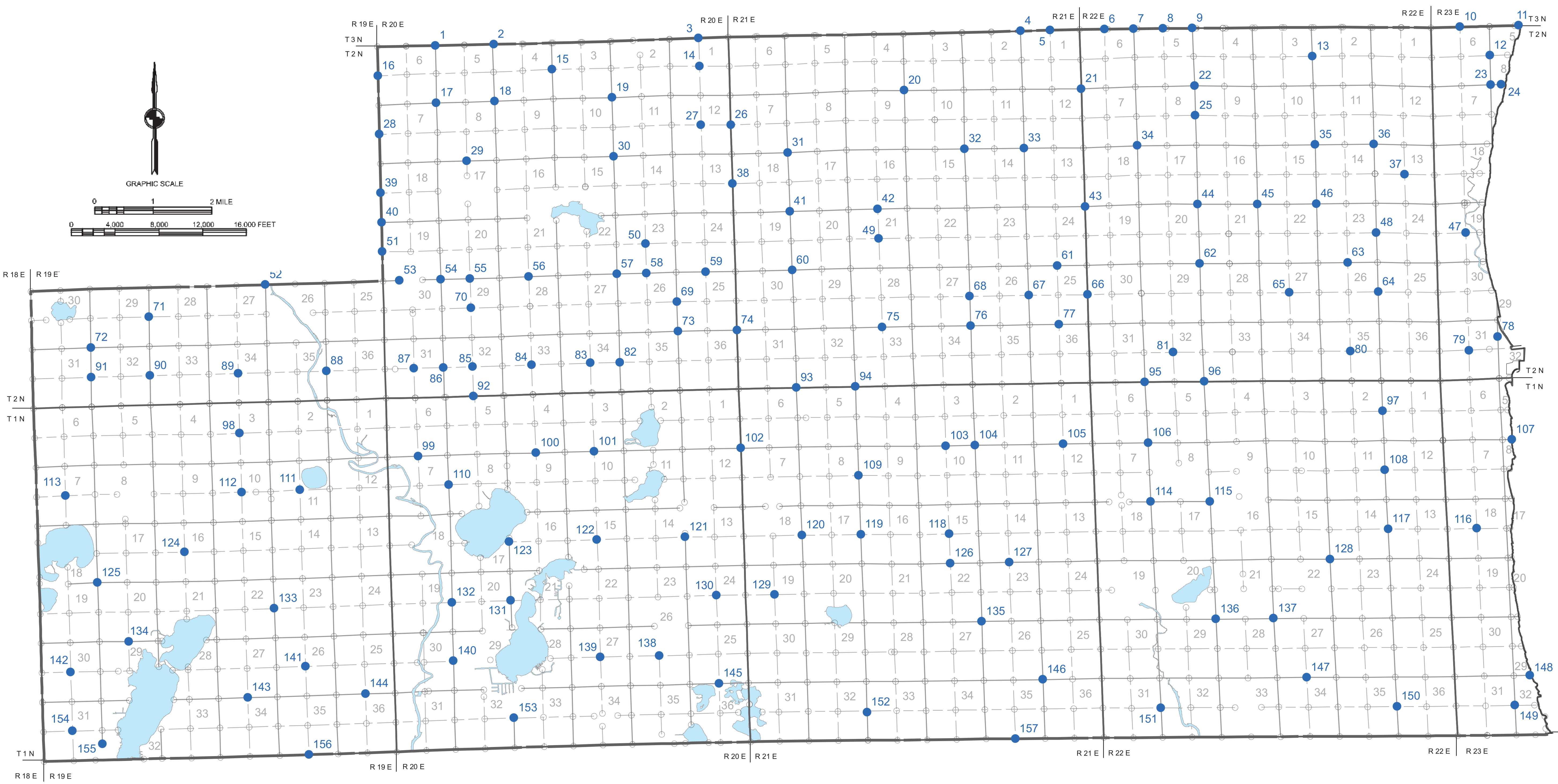


● MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS TO BE USED AS BASIS FOR DATUM CONVERSION COMPUTATIONS

Source: SEWRPC.

Figure 2

MAP OF KENOSHA COUNTY SHOWING U.S. PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO VERIFY COMPUTED COORDINATE POSITIONS

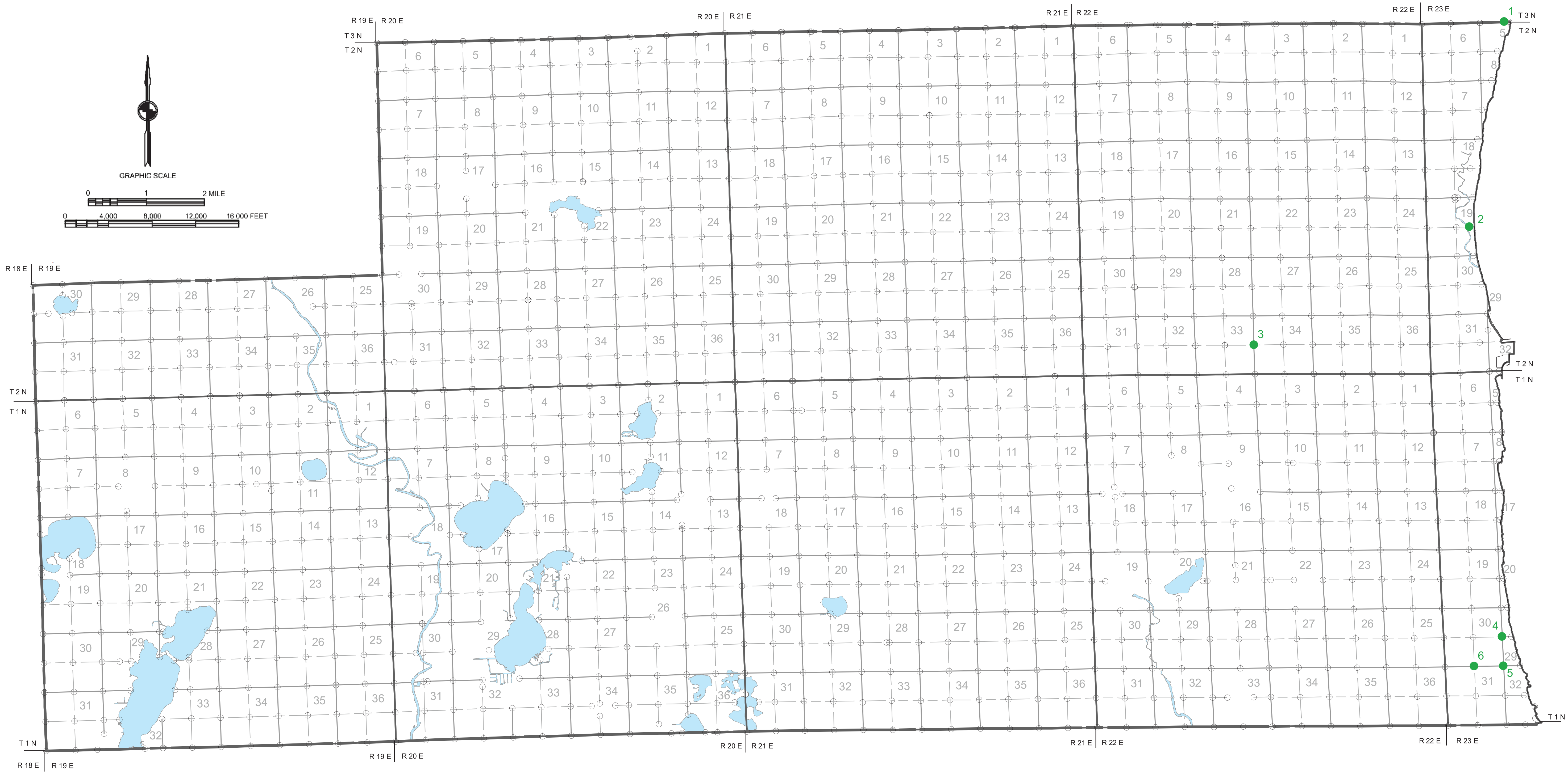


MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS RECORDING AN INDEPENDENT CHECK ON THE ACCURACY OF COMPUTED NAD83 (2011) COORDINATES

Source: *SEWRPC.*

Figure 3

MAP OF KENOSHA COUNTY SHOWING SIX U.S. PUBLIC LAND SURVEY CORNERS THE COMPUTED COORDINATES OF WHICH DID NOT MEET SURVEY CONTROL NETWORK ACCURACY STANDARDS



● MONUMENTED CORNERS NOT MEETING STANDARDS

Source: SEWRPC.

Figure 4

SAMPLE DOSSIER

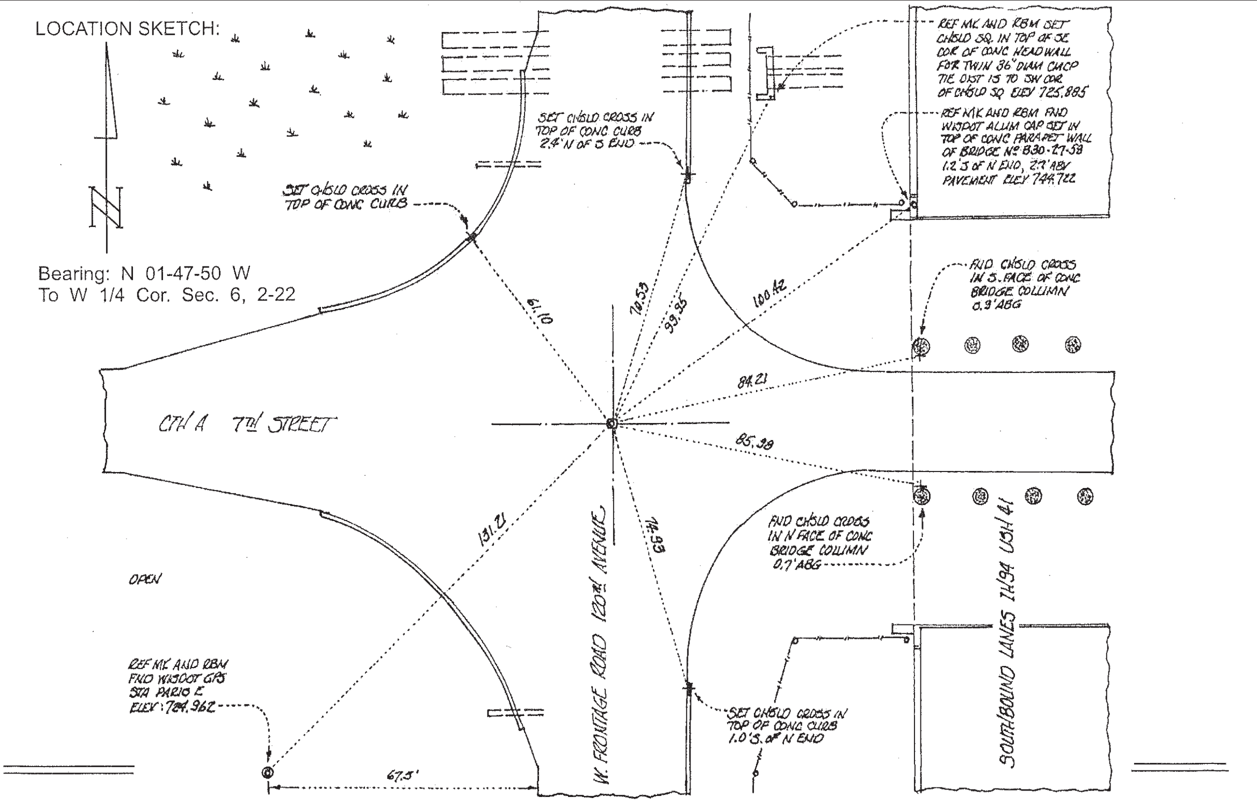
RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

U.S. PUBLIC LAND SURVEY CORNER 1|6 / 12|7 **T 02 N, R 21 E, KENOSHA 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. 1980	HOR. CONTROL: SEWRPC 2017
VERT. CONTROL: SEWRPC 2011	VERT. CONTROL:
NORTHING: 245,448.19 USFT	NORTHING: 245,459.31 USFT
EASTING: 2,550,596.65 USFT	EASTING: 2,519,061.05 USFT
ELEVATION: 726.597 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:



SURVEYOR'S AFFIDAVIT:
STATE OF WISCONSIN) SS
KENOSHA COUNTY)

As Kenosha County Surveyor, I hereby certify that following IH 94 west frontage road reconstruction, I set a concrete monument with SEWRPC brass cap to mark the location of this corner; replacing a broken concrete monument with stem of aluminum cap still in place; said concrete monument with Wisconsin Department of Transportation aluminum cap having been found and referenced by me on September 18, 1984; said concrete monument having been set to mark the location of this corner in November 1983 by James T. Fetzer, S-1028, Wisconsin Department of Transportation District Survey Supervisor, following frontage road reconstruction; replacing a concrete monument with Kenosha County brass cap set to mark the location of this corner in September 1974 by William A. Marescalco, S-826, former Kenosha County Surveyor, using information obtained from the Wisconsin Department of Transportation to perpetuate the location of this corner; that I have referenced the same as shown hereon; and that this record is correct and complete to the best of my knowledge and belief.

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

DATE OF SURVEY: 10 OCTOBER 2011 [signature] S - 157
REGISTERED LAND SURVEYOR

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

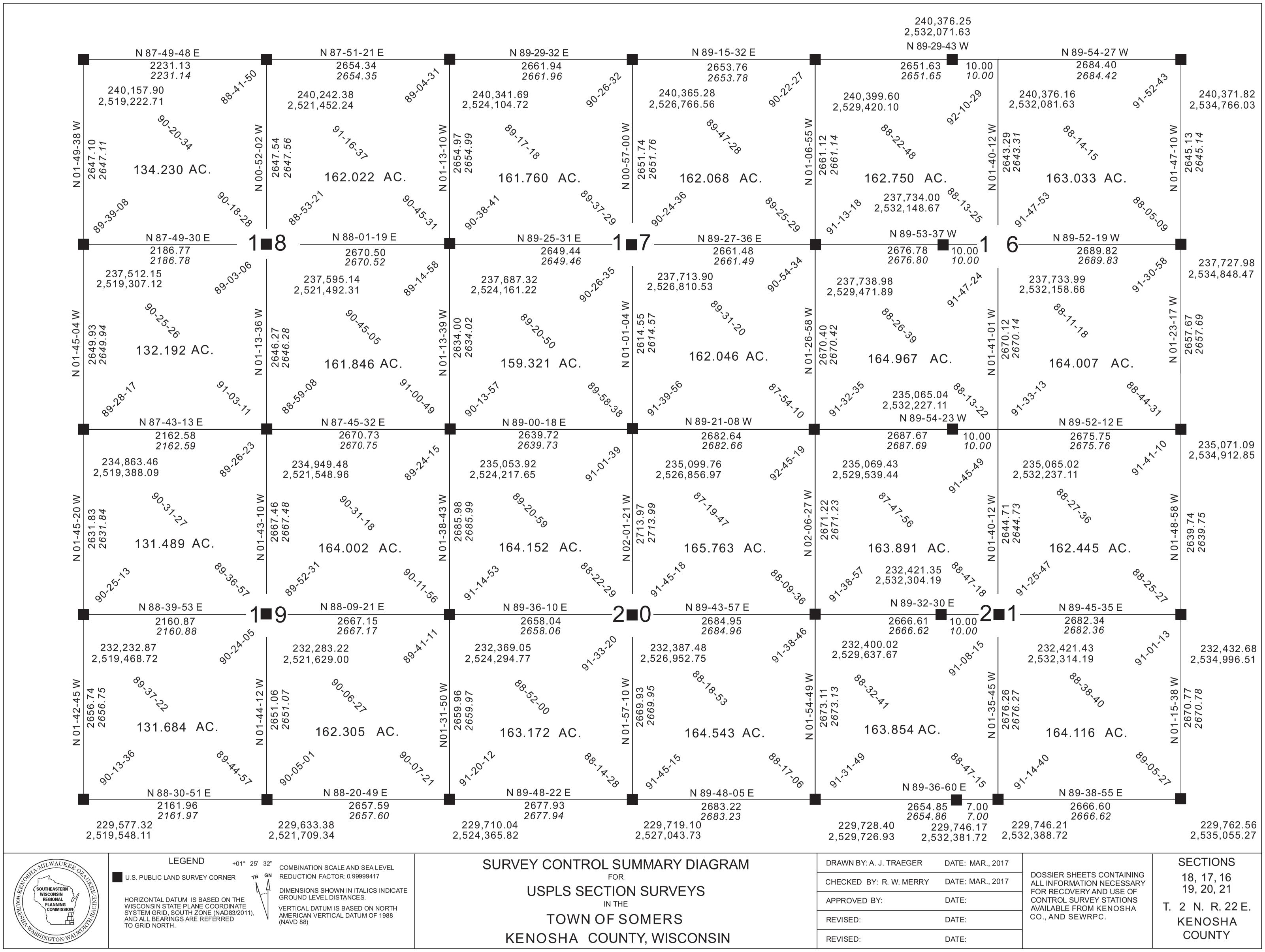
FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION (SEWRPC)
CERTIFICATION APPLIES ONLY TO THE LOCATION SKETCH AND SURVEYOR AFFIDAVIT

02210270 **27 –**

Source: SEWRPC.

Figure 5

SAMPLE CSSD



Source: SEWRPC.

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

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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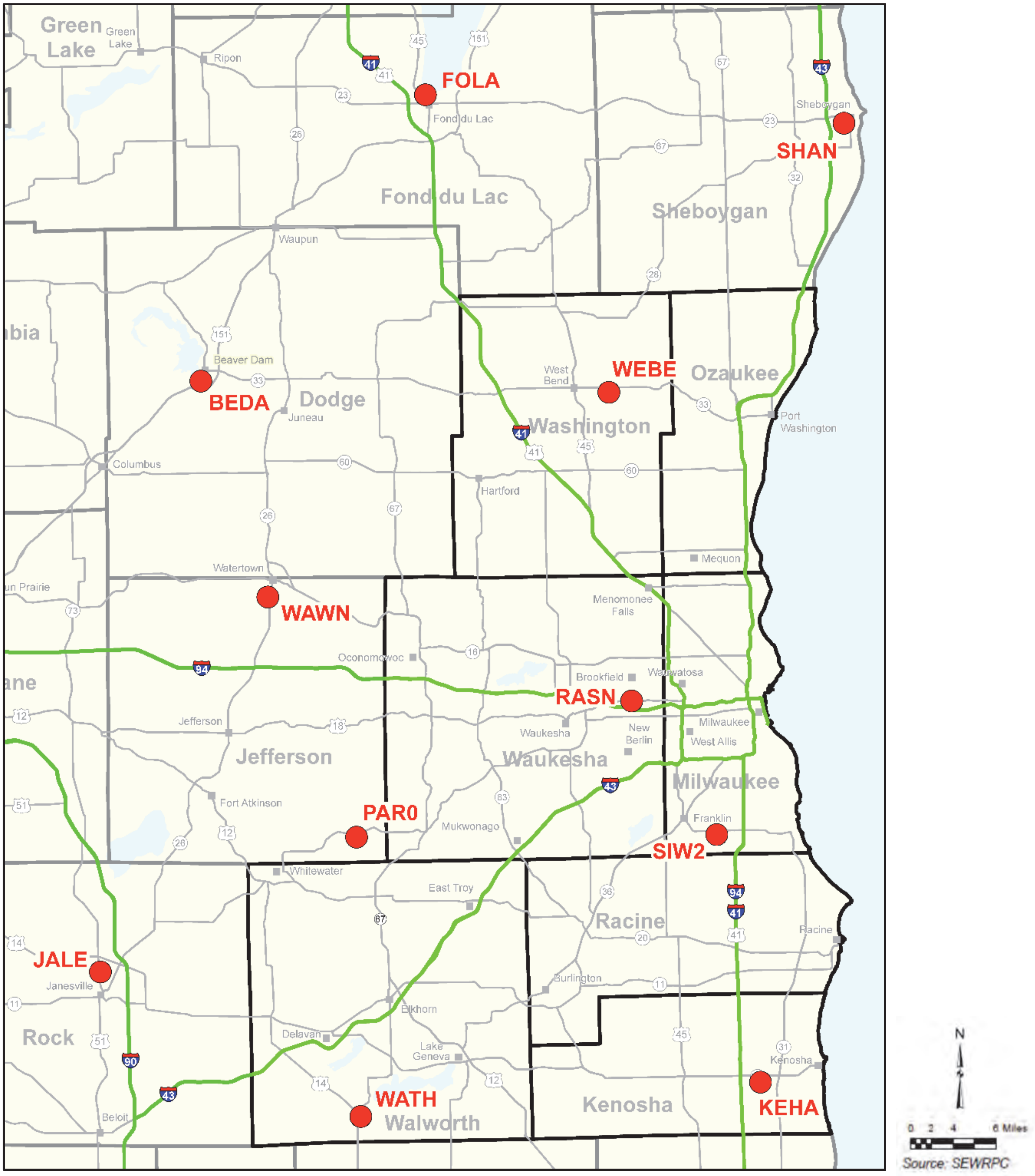
[1]*The term "least squares adjustment" refers to a mathematical procedure based on the theory of probability that derives the statistically most likely coordinate location of points defined by multiple measurements in a network. Moreover, a least squares adjustment defines a best-fit solution for weighed 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.

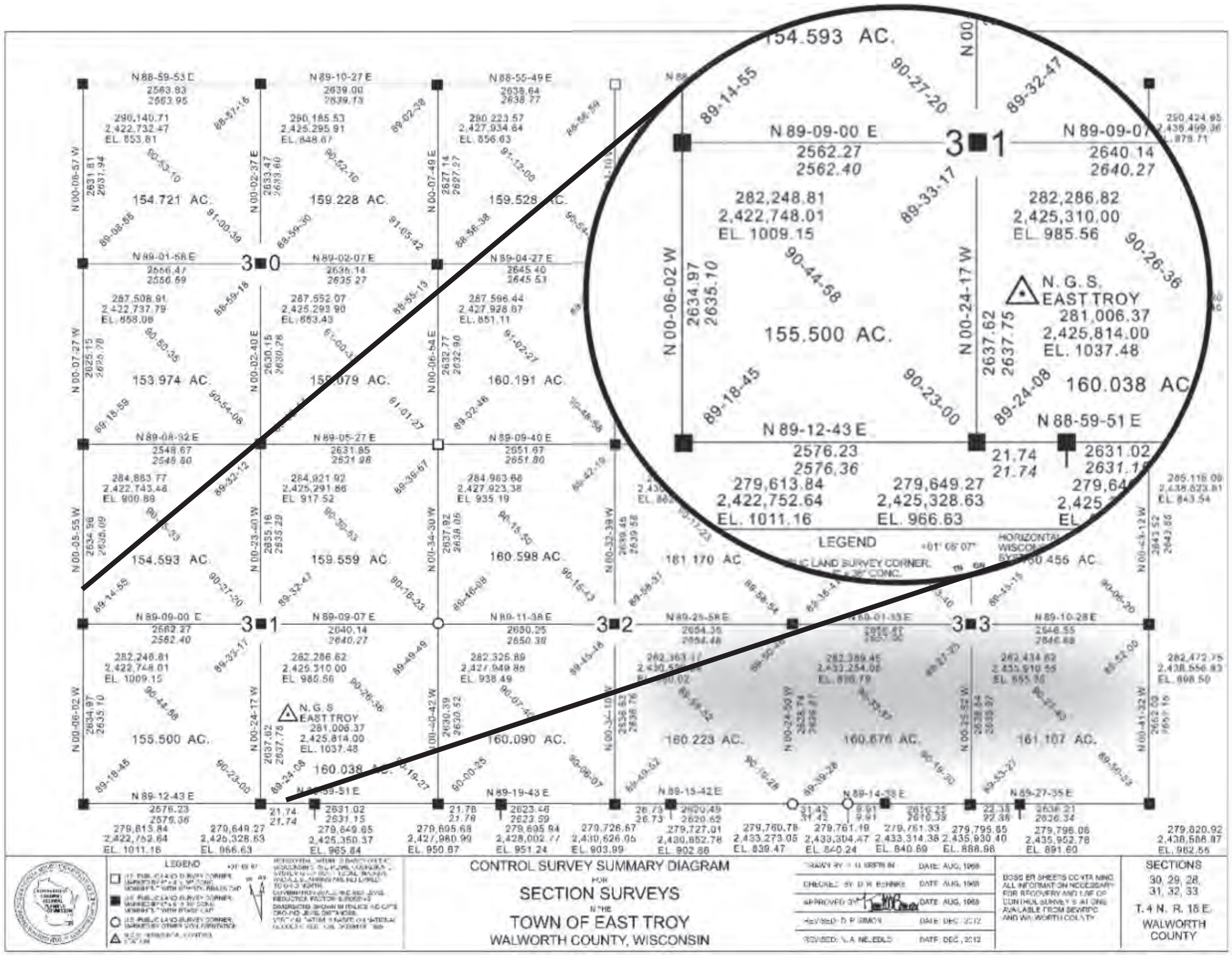
Computations

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).

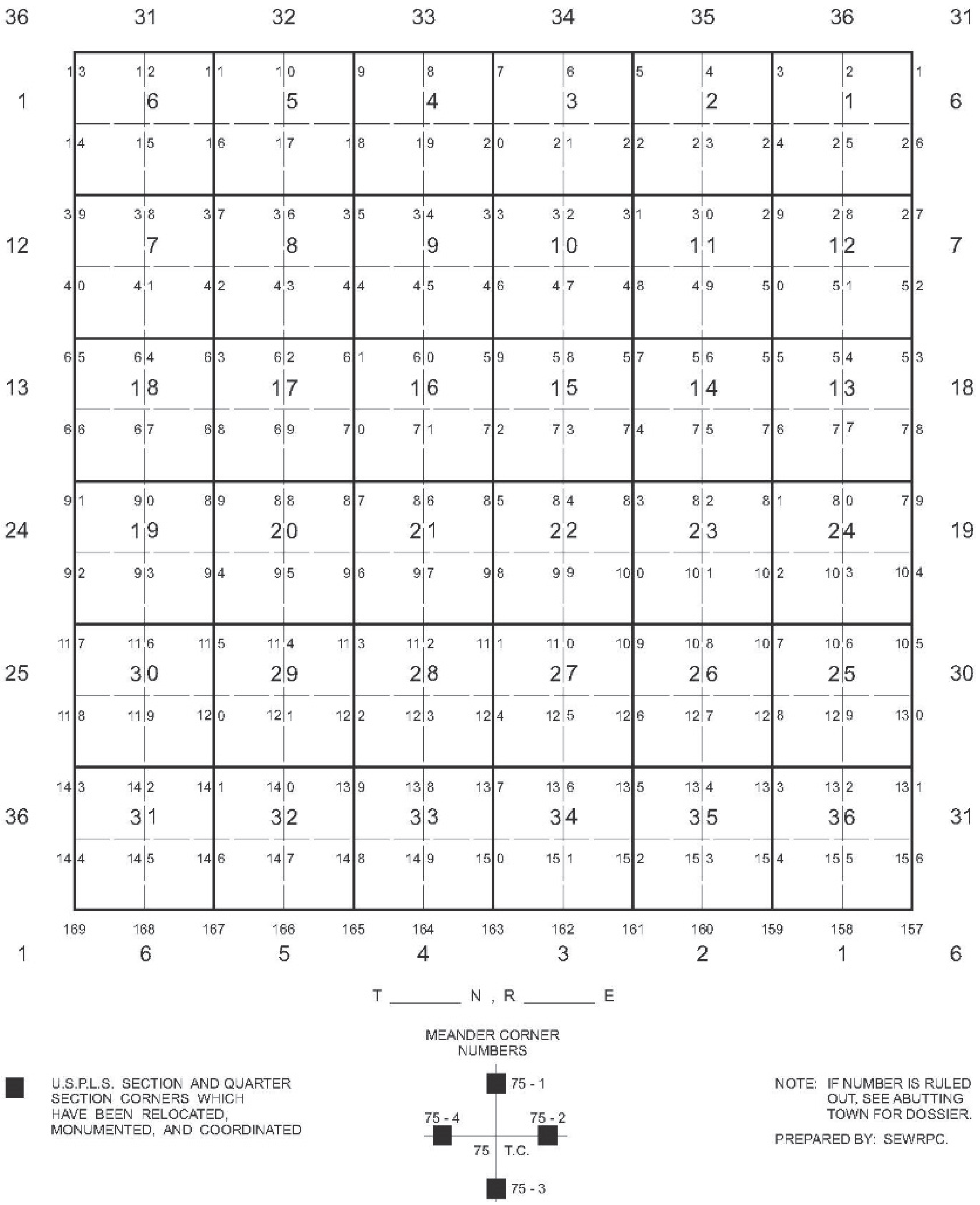
CONTROL SURVEY STATION NUMBERING

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



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.

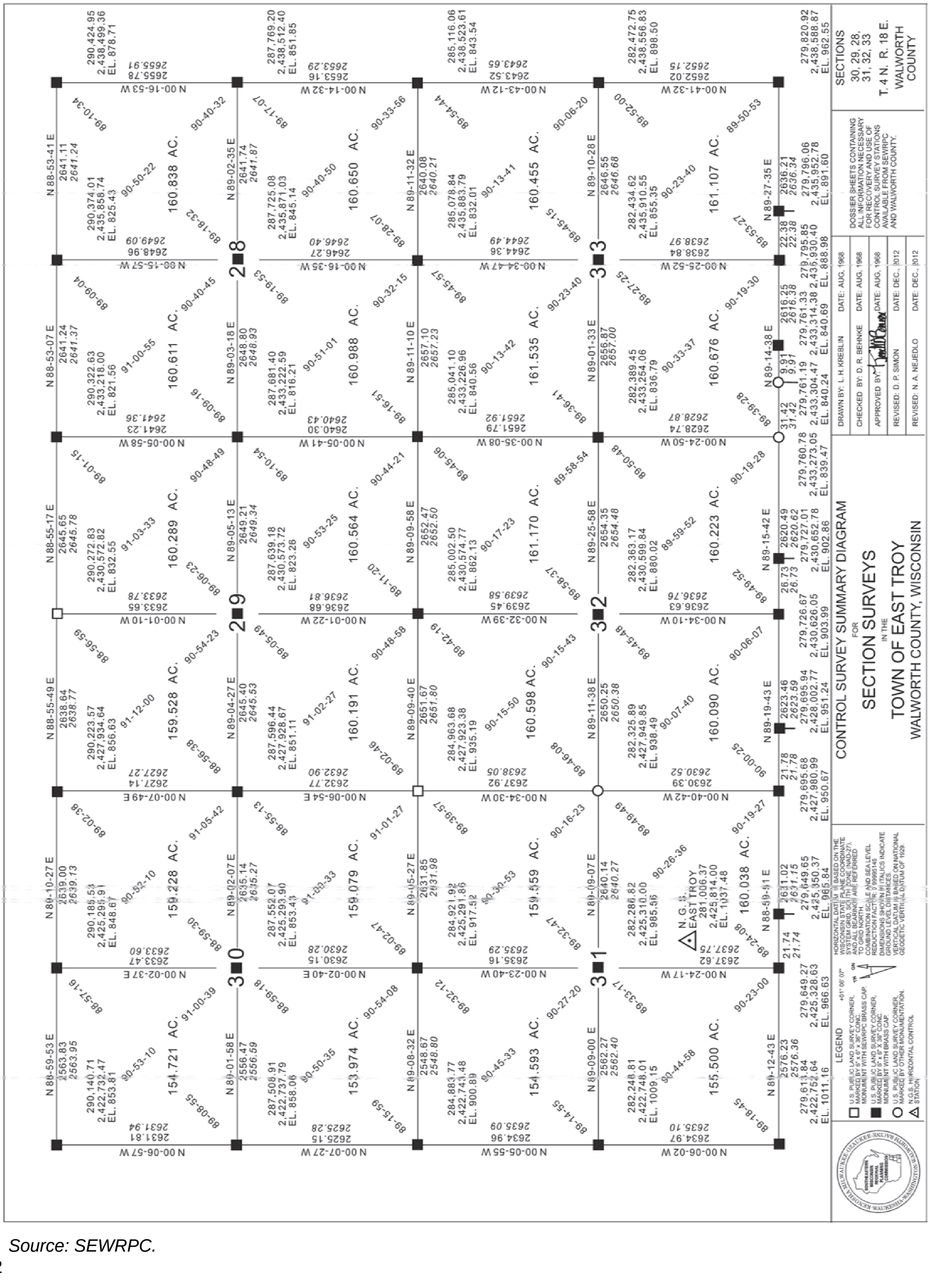
Since the completion of SEWRPC Technical Report No. 35, the Wisconsin Department of Transportation (WisDOT) in conjunction with NGS completed the Wisconsin Height Modernization Program (WI-HMP) within the Region. This program provided high-order orthometric height data on a carefully distributed network 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

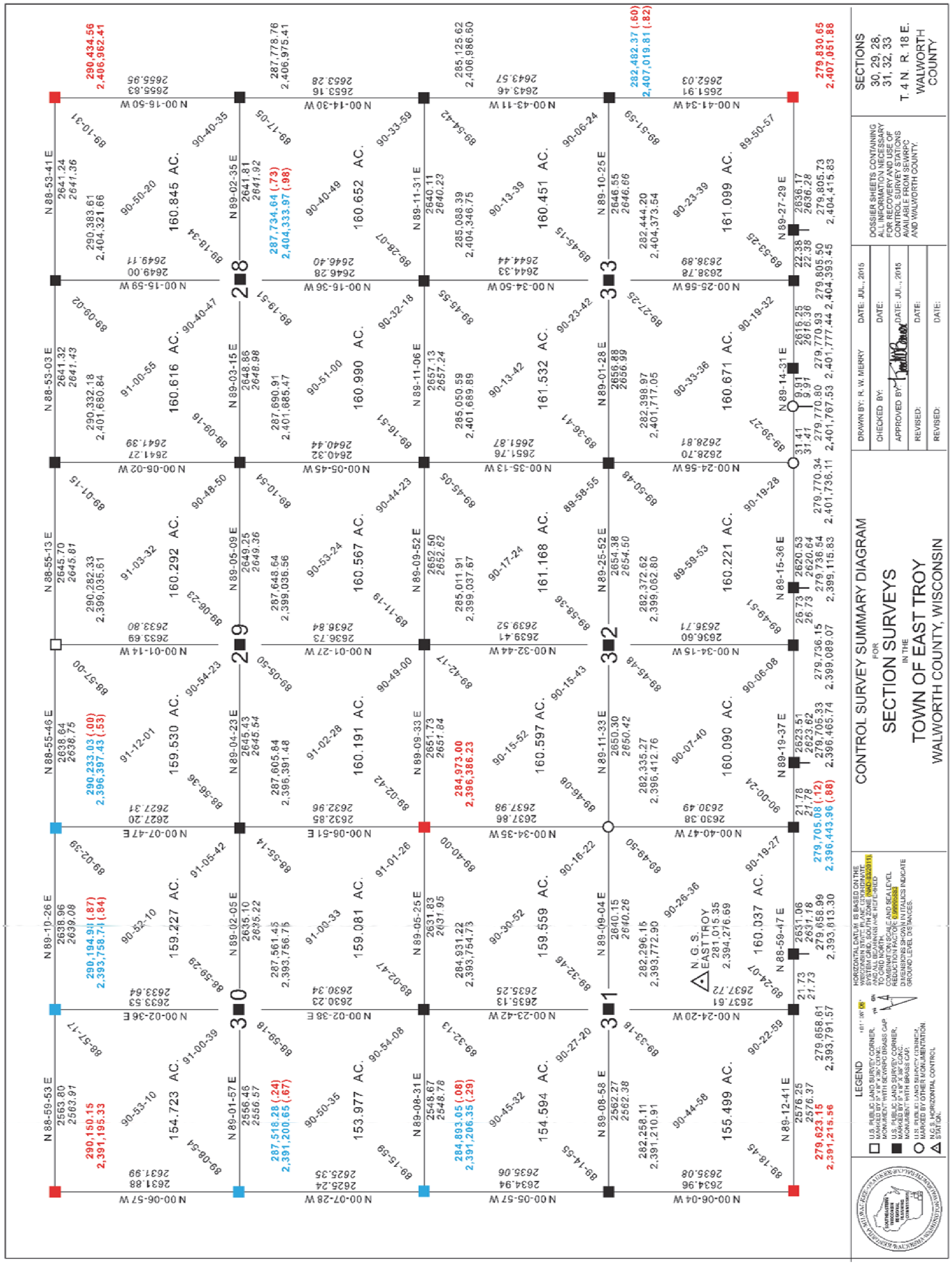
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 27



Source: SEWRPC.

Figure 5

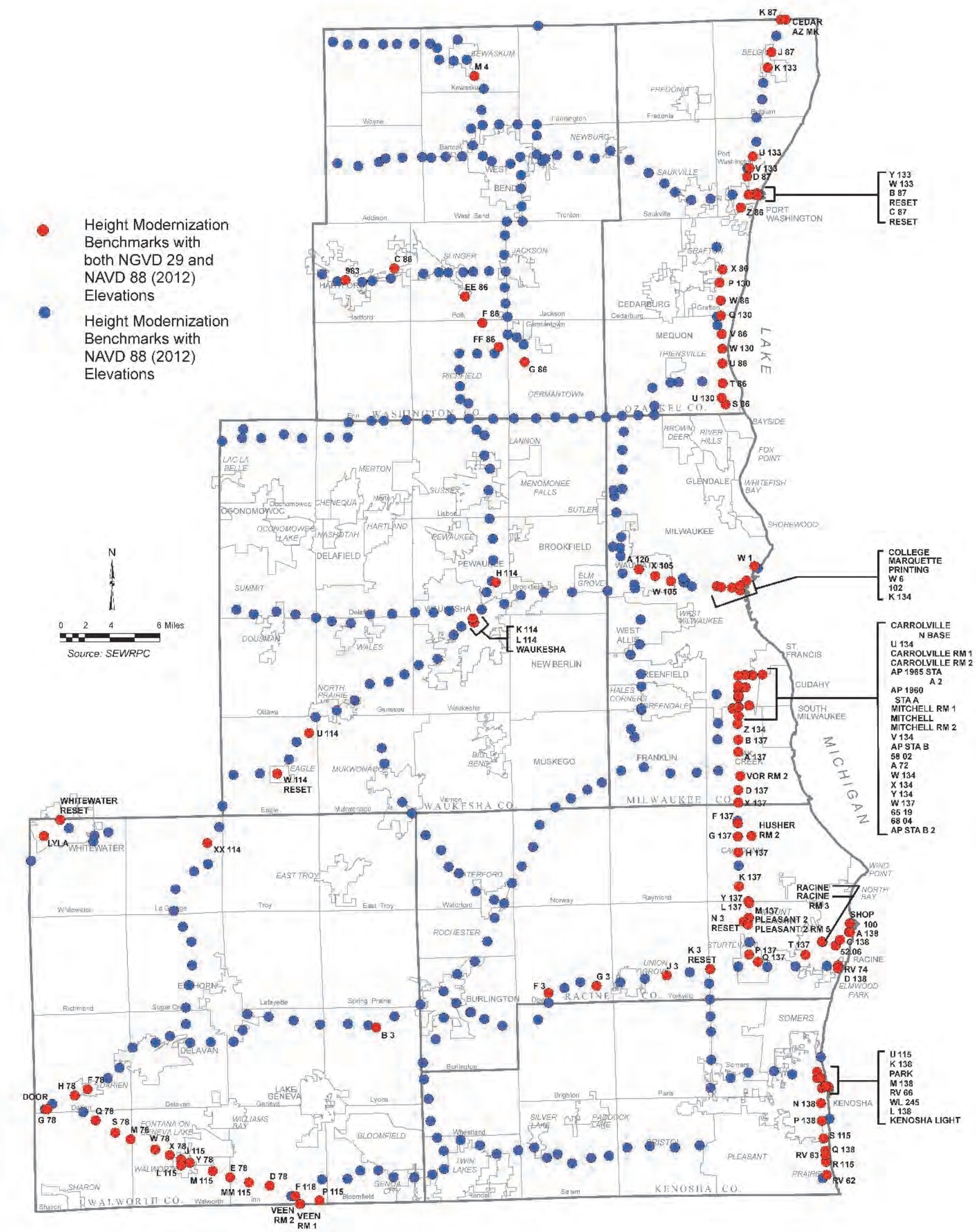
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 83 (2011)



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

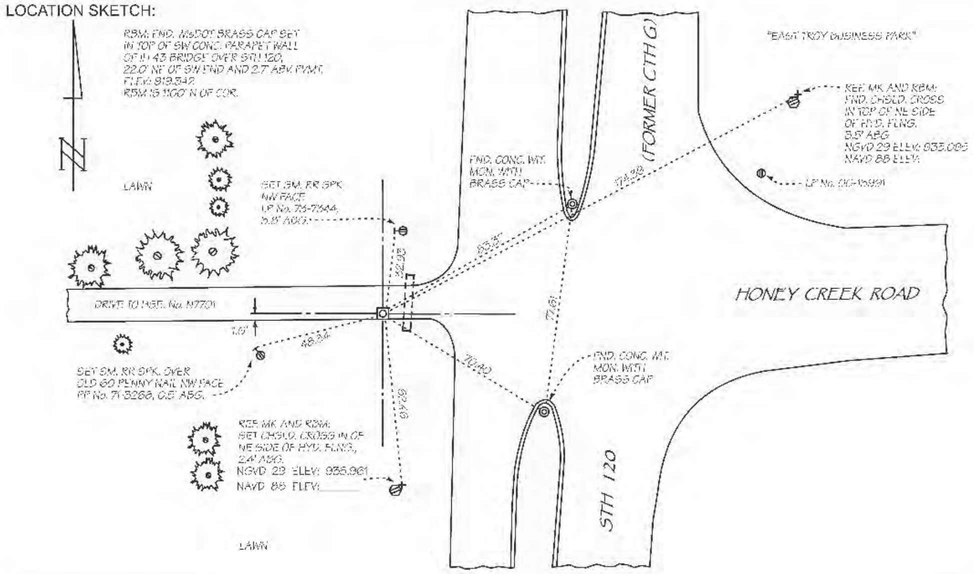
REVISED "RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION"

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.