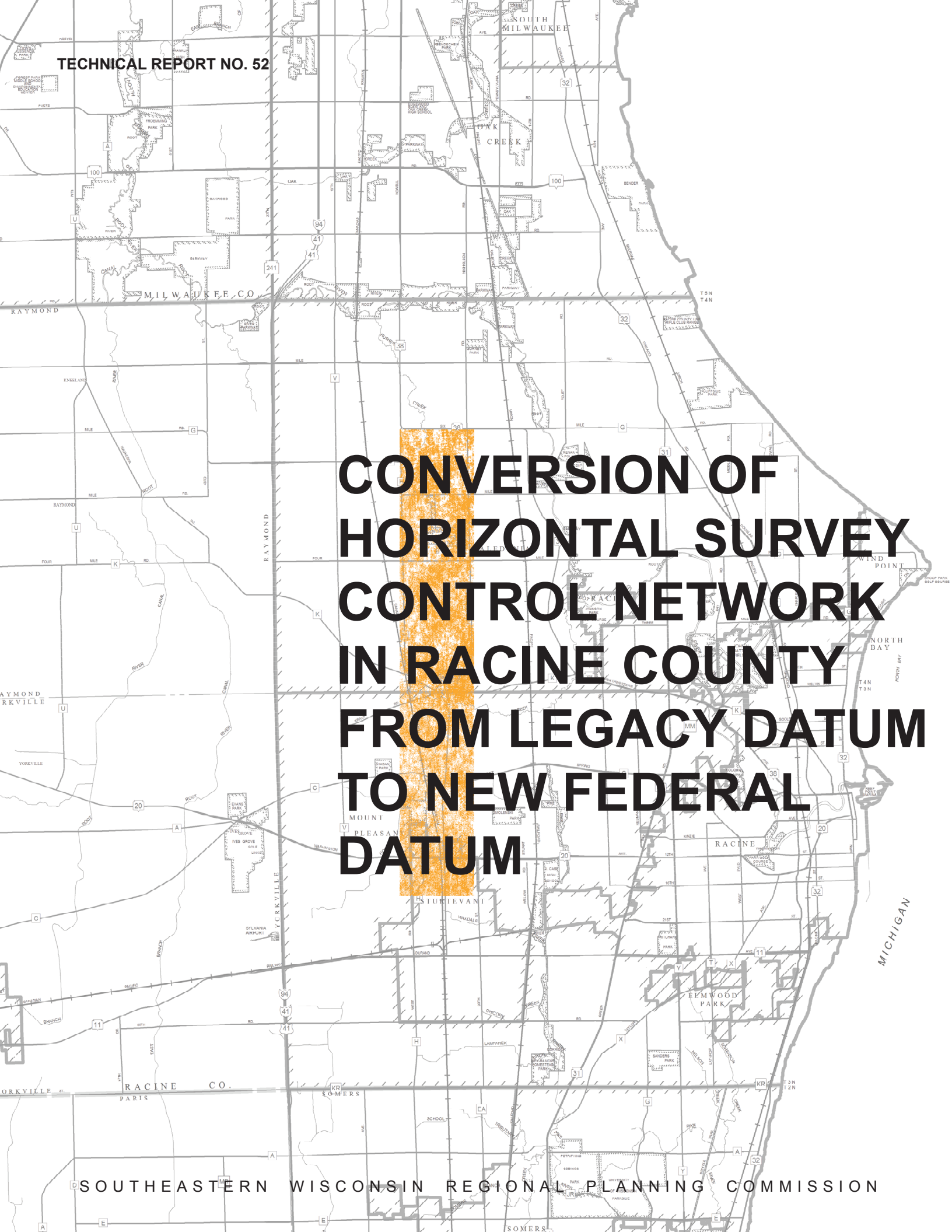
TECHNICAL REPORT NO. 52

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



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

Prepared by the

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

April 2017

$10.00

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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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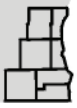

April 27, 2017

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 September 14, 2016, the Commission entered into an agreement with Racine County governing the conversion of the survey control network within the County from the legacy horizontal datum to the new Federal datum. Racine County thus became the second county within the Region to undertake a datum conversion project—the first being Kenosha County.

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

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 benchmarks to provide a reliable vertical survey control network fully integrated with the horizontal survey control network.

Through the cooperative efforts of the Commission and its constituent counties and municipalities, the recommended 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—U.S. Public Land Survey System corners—comprising 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 the 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.

In 1973, the Federal government 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 the Geodetic Reference System of 1980 (GRS 80). The new horizontal datum was subsequently readjusted to create NAD 83 (2011). In 1977, the Federal government 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 would 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 by 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 horizontal and vertical 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 the datum conversions within the Region and to request Commission assistance in making the desired conversions. 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 horizontal 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 for all horizontal survey control stations—U.S. Public Land Survey System corners within each county of the Region—by occupying all of the stations for further GPS observations. The procedure, while providing a high level of accuracy in the new horizontal 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 in that report for datum conversion. 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, 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.

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[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 Memorandum Report 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 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 the revised horizontal datum conversion procedure developed by the Commission staff. The Addendum accordingly recommended that each of the individual county land information system managers within the Region determine whether or not their agency—the county land information council concerned—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 county 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 September 14, 2016, Racine County entered into an agreement with the Commission under which the Commission would convert the State Plane Coordinate positions of all 1,531 U.S. Public Land Survey System corners within the County from the legacy datum—NAD 27—to the new Federal datum—NAD 83 (2011). Racine County thus became the second county within the Region to enter into an agreement with the Commission governing datum conversion. 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 appended to this report. 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, 163 remonumented U.S. Public Land Survey System corners were recovered and occupied for GPS measurement or, for corners located along the Racine-Kenosha County line were assigned the coordinate positions determined for the corners concerned in the conduct of the Kenosha County datum conversion project. The location of these corners is shown on Figure 1 appended. The State Plane Coordinates of these corners 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 one 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 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 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 utilizes 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.

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 each of five areas of the County 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 five areas concerned are shown on Figure 2. Area A contains a cluster of 24 stations, Area B a cluster of 12 stations, Area C a cluster of 8 stations, Area D a cluster of 36 stations, and Area E a cluster of 17 stations. The discrepancies found in the positions of the stations within each area ranged in feet as follows:

Area	No. of Stations	Northing	Easting
A	24	-0.33 to +1.01	-0.18 to +0.66
B	12	+0.01 to +0.43	-0.06 to +0.67
C	8	-0.28 to +0.18	-0.18 to +0.51
D	36	-0.66 to +0.26	-0.29 to +0.75
E	17	-0.30 to +0.25	-0.18 to +0.48

Further analyses indicated that the discrepancies found could most likely be attributed to errors or blunders made in the conduct of the precise traverses used to determine the legacy positions 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. Of the 97 errant stations, 45 were so occupied. These 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 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 within the five problem areas previously described, discrepancies in the location of three stations were also found. These stations are also shown on Figure 2. Stations number 1 and 2, as shown on Figure 2, consisted of a standard U.S. Public Land Survey System corner and an adjacent closing corner. The discrepancies found in these two corner locations ranged from 1.43 feet to 1.49 feet in Northing, and from 0.22 feet to 0.26 feet in Easting. Investigation of the history of the monumentation marking these two stations, as given by the dossier sheets on record for the stations, indicated that the discrepancies found were most probably caused by an error in the positioning of replacement monuments with respect to the location of the monuments replaced, and therefore, with respect to the true position of the station. A similar conclusion was reached with respect to Station No. 3 as shown on Figure 2, with the discrepancy found in the position of this closing station being 0.30 feet in Northing, and 0.09 feet in Easting. The positions of these three 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. The County Surveyor should relocate the three monuments concerned so that they conform to the true location of the corners concerned as and the positions given in the survey control summary diagrams delivered to the County under this project.

FIELD VERIFICATION OF COMPUTED CORNER POSITIONS

To check the accuracy of the computed survey control station coordinates, an approximately 13 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 198 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 0.185 of a foot, while the largest difference between a measured and a computed easting was also 0.179 of a foot. The average of the differences between the measured and computed Northings was -0.008 of a foot, and of the Eastings also -0.002 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 0.077 seconds of latitude, and 0.288 seconds of longitude, equivalent to about 7.6 feet and 28.3 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 Racine 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 1,531 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 60 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. Eighteen revised survey control summary diagrams were also provided reflecting the changes to the legacy data made as a part of this project.

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
1	311678.86	2430616.33
2	312470.62	2454409.95
3	312535.83	2456947.60
4	312611.27	2459619.11
5	313024.71	2472837.61
6	313099.16	2475493.97
7	313169.78	2478146.31
8	313232.68	2480797.99
9	313358.01	2486092.38
10	313443.37	2488734.96
11	313507.54	2491374.48
12	313588.52	2494012.72
13	313669.60	2496650.92
14	313749.55	2499285.00
15	313829.23	2501919.28
16	313957.22	2507189.39
17	314025.08	2509829.51
18	314082.24	2512461.31
19	314194.45	2517710.35
20	314224.66	2522802.07
21	314268.94	2528063.74
22	314306.44	2533188.36
23	314404.83	2543777.03
24	311040.62	2422710.34
25	309541.70	2438584.02
26	309795.82	2446475.99
27	309172.04	2525329.85
28	309383.05	2551787.30
29	306596.55	2541227.63
30	304242.54	2438650.60
31	302087.17	2454537.46
32	302632.84	2470278.04
33	302989.92	2486148.39
34	303573.13	2501836.60
35	303813.97	2517805.94

Corner Number	Northing	Easting
36	303899.20	2533317.68
37	303915.86	2549204.06
38	301703.23	2559928.80
39	300308.86	2449281.60
40	298085.38	2493909.13
41	298418.13	2509882.22
42	298580.05	2522850.59
43	298641.65	2541351.60
44	299076.09	2562599.61
45	293552.66	2433449.30
46	290501.39	2422864.25
47	292073.41	2470349.47
48	292963.20	2501986.34
49	293210.42	2517879.20
50	293302.43	2533519.15
51	293594.60	2549354.42
52	293976.74	2569244.18
53	291317.41	2568310.73
54	289768.93	2480959.05
55	288941.40	2454618.61
56	285719.46	2438763.41
57	287441.92	2494085.80
58	287812.64	2509995.36
59	288400.54	2557340.77
60	283660.37	2454623.20
61	280599.86	2444055.32
62	281942.14	2486324.95
63	282351.71	2502139.99
64	282653.46	2517995.02
65	282711.57	2531079.42
66	277390.75	2525925.52
67	276184.11	2475937.96
68	275803.28	2460092.78
69	275397.55	2449543.30
70	275053.05	2436348.92

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
201	227240.35	2424515.53
202	227324.03	2427182.80
203	227444.26	2429831.95
204	227509.51	2432479.63
205	227567.28	2435132.42
206	227621.02	2437754.84
207	227674.89	2440377.21
208	227748.68	2443013.18
209	227828.55	2445646.05

Corner Number	Northing	Easting
210	227907.59	2448314.73
211	227985.78	2450951.18
212	228073.18	2453586.68
213	228160.68	2456222.13
214	230802.17	2456158.83
215	233436.17	2456095.58
216	236078.11	2456023.54
217	238713.14	2455957.91
218	241359.01	2455898.57
219	243976.01	2455836.03
220	246618.82	2455782.52
221	249259.14	2455729.09
222	249302.56	2458277.00
223	249347.53	2460909.14
224	249404.54	2463553.03
225	249461.15	2466195.96
226	249511.78	2468840.43
227	249585.20	2471486.78
228	249662.80	2474125.35
229	249737.44	2476765.80
230	249836.57	2479377.54
231	249936.26	2482006.76
232	250033.35	2484646.72
233	250111.63	2487290.61
234	250171.10	2489843.19
235	250232.61	2492482.19
236	250281.50	2495123.42
237	250318.18	2497767.92
238	250364.49	2500410.60
239	250408.07	2503057.45
240	250466.46	2505697.79
241	250528.21	2508341.09
242	250594.75	2510980.48
243	250661.16	2513619.83
244	250728.82	2516254.74
245	250796.34	2518899.48
246	250823.28	2521426.61
247	250855.90	2524085.40
248	250888.41	2526744.27
249	250912.12	2529383.49

Table 1 (continued)

Corner Number	Northing	Easting
250	250934.03	2532055.48
251	250963.37	2534666.89
252	250983.19	2537306.79
253	250989.14	2539947.46
254	251006.68	2542587.84
255	250997.07	2545226.38

Corner Number	Northing	Easting
256	250986.99	2547864.73
257	250966.11	2550504.78
258	251027.89	2553138.50
259	251085.32	2555787.04
260	251161.19	2558418.20

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	282723.980	2533697.160
	GPS Observed	282725.405	2533697.417
	Difference	1.425	0.257
2	Computed	282724.120	2533725.810
	GPS Observed	282725.615	2533726.028
	Difference	1.495	0.218
3	Computed	248663.810	2437251.370
	GPS Observed	248664.109	2437251.459
	Difference	0.299	0.089

CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 2.

Source: SEWRPC.

Table 3

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

Corner Number		Northing	Easting
1	Computed	312537.510	2457007.220
	GPS Observed	312537.371	2457007.225
	Difference	-0.139	0.005
2	Computed	312612.220	2459646.730
	GPS Observed	312612.185	2459646.696
	Difference	-0.035	-0.034
3	Computed	312688.580	2462290.370
	GPS Observed	312688.514	2462290.310
	Difference	-0.066	-0.060
4	Computed	313025.280	2472857.960
	GPS Observed	313025.288	2472857.902
	Difference	0.008	-0.058
5	Computed	313099.950	2475523.400
	GPS Observed	313099.803	2475523.421
	Difference	-0.147	0.021
6	Computed	313170.360	2478170.550
	GPS Observed	313170.379	2478170.525
	Difference	0.019	-0.025
7	Computed	313232.980	2480810.770
	GPS Observed	313232.850	2480810.769
	Difference	-0.130	-0.001
8	Computed	313295.510	2483451.680
	GPS Observed	313295.601	2483451.660
	Difference	0.091	-0.020
9	Computed	313434.300	2488453.960
	GPS Observed	313434.467	2488453.970
	Difference	0.167	0.010
10	Computed	313500.710	2491093.420
	GPS Observed	313500.733	2491093.412
	Difference	0.023	-0.008
11	Computed	313580.940	2493765.800
	GPS Observed	313580.967	2493765.756
	Difference	0.027	-0.044
12	Computed	313663.060	2496437.860
	GPS Observed	313663.021	2496437.907
	Difference	-0.039	0.047
13	Computed	313743.300	2499079.190
	GPS Observed	313743.470	2499079.131
	Difference	0.170	-0.059
14	Computed	313823.220	2501720.720
	GPS Observed	313823.371	2501720.593
	Difference	0.151	-0.127
15	Computed	314080.400	2512376.560
	GPS Observed	314080.389	2512376.584
	Difference	-0.011	0.024
16	Computed	314224.110	2522660.840
	GPS Observed	314224.143	2522660.927
	Difference	0.033	0.087
17	Computed	314267.970	2527906.980
	GPS Observed	314267.895	2527906.950
	Difference	-0.075	-0.030
18	Computed	311792.790	2527922.320
	GPS Observed	311792.797	2527922.310
	Difference	0.007	-0.010
19	Computed	311677.240	2509722.540
	GPS Observed	311677.270	2509722.555
	Difference	0.030	0.015
20	Computed	311553.030	2501752.890
	GPS Observed	311553.059	2501752.948
	Difference	0.029	0.058
21	Computed	309505.810	2435955.890
	GPS Observed	309505.821	2435955.938
	Difference	0.011	0.048
22	Computed	306700.780	2430671.440
	GPS Observed	306700.759	2430671.577
	Difference	-0.021	0.137

Table 3 (continued)

Corner Number		Northing	Easting
23	Computed	307151.160	2446523.470
	GPS Observed	307151.190	2446523.293
	Difference	0.030	-0.177
24	Computed	307247.810	2449174.720
	GPS Observed	307247.705	2449174.587
	Difference	-0.105	-0.133
25	Computed	307722.000	2462341.340
	GPS Observed	307722.042	2462341.429
	Difference	0.042	0.089
26	Computed	307810.080	2464985.520
	GPS Observed	307810.184	2464985.650
	Difference	0.104	0.130
27	Computed	307988.500	2471563.600
	GPS Observed	307988.326	2471563.675
	Difference	-0.174	0.075
28	Computed	308194.390	2478188.100
	GPS Observed	308194.311	2478188.012
	Difference	-0.079	-0.088
29	Computed	308279.910	2480839.760
	GPS Observed	308280.031	2480839.741
	Difference	0.121	-0.019
30	Computed	308402.550	2488492.480
	GPS Observed	308402.418	2488492.442
	Difference	-0.132	-0.038
31	Computed	308705.790	2493798.650
	GPS Observed	308705.681	2493798.823
	Difference	-0.109	0.173
32	Computed	308838.090	2496460.180
	GPS Observed	308838.008	2496460.298
	Difference	-0.082	0.118
33	Computed	308898.340	2501777.430
	GPS Observed	308898.390	2501777.528
	Difference	0.050	0.098
34	Computed	309187.680	2535871.920
	GPS Observed	309187.601	2535872.012
	Difference	-0.079	0.092
35	Computed	309243.270	2541207.090
	GPS Observed	309243.271	2541207.177
	Difference	0.001	0.087
36	Computed	306607.160	2546545.840
	GPS Observed	306607.066	2546545.983
	Difference	-0.094	0.143
37	Computed	306515.290	2527969.280
	GPS Observed	306515.178	2527969.119
	Difference	-0.112	-0.161
38	Computed	306418.380	2512459.100
	GPS Observed	306418.522	2512459.160
	Difference	0.142	0.060
39	Computed	306276.270	2504457.640
	GPS Observed	306276.364	2504457.755
	Difference	0.094	0.115
40	Computed	304050.030	2430711.620
	GPS Observed	304049.888	2430711.731
	Difference	-0.142	0.111
41	Computed	301166.460	2425432.850
	GPS Observed	301166.356	2425432.845
	Difference	-0.104	-0.005
42	Computed	301398.920	2430750.810
	GPS Observed	301398.791	2430750.889
	Difference	-0.129	0.079
43	Computed	301992.870	2449809.200
	GPS Observed	301992.855	2449809.183
	Difference	-0.015	-0.017
44	Computed	302347.050	2461203.360
	GPS Observed	302347.152	2461203.256
	Difference	0.102	-0.104
45	Computed	303670.650	2507132.990
	GPS Observed	303670.551	2507133.058
	Difference	-0.099	0.068
46	Computed	303892.560	2538562.740
	GPS Observed	303892.519	2538562.886
	Difference	-0.041	0.146

Table 3 (continued)

Corner Number		Northing	Easting
47	Computed	301648.290	2554556.040
	GPS Observed	301648.360	2554556.137
	Difference	0.070	0.097
48	Computed	301233.800	2525424.020
	GPS Observed	301233.776	2525423.859
	Difference	-0.024	-0.161
49	Computed	301109.220	2512517.260
	GPS Observed	301109.212	2512517.179
	Difference	-0.008	-0.081
50	Computed	300614.550	2491220.430
	GPS Observed	300614.642	2491220.502
	Difference	0.092	0.072
51	Computed	297351.010	2470342.700
	GPS Observed	297350.993	2470342.604
	Difference	-0.017	-0.096
52	Computed	297666.010	2478244.600
	GPS Observed	297666.195	2478244.550
	Difference	0.185	-0.050
53	Computed	297691.240	2480904.480
	GPS Observed	297691.134	2480904.327
	Difference	-0.106	-0.153
54	Computed	298175.160	2496585.140
	GPS Observed	298175.344	2496585.056
	Difference	0.184	-0.084
55	Computed	298319.790	2504560.890
	GPS Observed	298319.684	2504560.928
	Difference	-0.106	0.038
56	Computed	298585.080	2530744.640
	GPS Observed	298585.092	2530744.515
	Difference	0.012	-0.125
57	Computed	298606.110	2536030.920
	GPS Observed	298606.095	2536030.791
	Difference	-0.015	-0.129
58	Computed	298986.350	2554557.050
	GPS Observed	298986.390	2554557.146
	Difference	0.040	0.096

Corner Number		Northing	Easting
59	Computed	296398.930	2559970.080
	GPS Observed	296398.892	2559970.210
	Difference	-0.038	0.130
60	Computed	296024.840	2544020.860
	GPS Observed	296024.902	2544020.683
	Difference	0.062	-0.177
61	Computed	295326.930	2491290.040
	GPS Observed	295327.049	2491290.025
	Difference	0.119	-0.015
62	Computed	295051.810	2480931.380
	GPS Observed	295051.694	2480931.411
	Difference	-0.116	0.031
63	Computed	294278.640	2457166.310
	GPS Observed	294278.735	2457166.463
	Difference	0.095	0.153
64	Computed	294051.700	2449706.580
	GPS Observed	294051.526	2449706.674
	Difference	-0.174	0.094
65	Computed	293847.550	2444055.790
	GPS Observed	293847.553	2444055.665
	Difference	0.003	-0.125
66	Computed	290597.990	2425496.610
	GPS Observed	290597.836	2425496.761
	Difference	-0.154	0.151
67	Computed	290887.950	2433467.080
	GPS Observed	290887.910	2433467.152
	Difference	-0.040	0.072
68	Computed	291199.620	2444057.960
	GPS Observed	291199.660	2444057.850
	Difference	0.040	-0.110
69	Computed	291648.350	2457170.090
	GPS Observed	291648.206	2457170.163
	Difference	-0.144	0.073
70	Computed	292411.390	2480948.610
	GPS Observed	292411.435	2480948.644
	Difference	0.045	0.034

Table 3 (continued)

Corner Number		Northing	Easting
71	Computed	292443.730	2486231.500
	GPS Observed	292443.727	2486231.503
	Difference	-0.003	0.003
72	Computed	293020.500	2504638.150
	GPS Observed	293020.542	2504638.199
	Difference	0.042	0.049
73	Computed	293323.120	2538781.970
	GPS Observed	293323.136	2538782.061
	Difference	0.016	0.091
74	Computed	293654.960	2554601.730
	GPS Observed	293655.002	2554601.822
	Difference	0.042	0.092
75	Computed	293885.810	2565282.810
	GPS Observed	293885.842	2565282.962
	Difference	0.032	0.152
76	Computed	289912.400	2488733.470
	GPS Observed	289912.573	2488733.563
	Difference	0.173	0.093
77	Computed	289084.280	2459814.020
	GPS Observed	289084.309	2459814.024
	Difference	0.029	0.004
78	Computed	288743.970	2449323.320
	GPS Observed	288743.952	2449323.425
	Difference	-0.018	0.105
79	Computed	288545.350	2444058.760
	GPS Observed	288545.441	2444058.676
	Difference	0.091	-0.084
80	Computed	285320.240	2425506.470
	GPS Observed	285320.202	2425506.521
	Difference	-0.038	0.051
81	Computed	285485.180	2430806.760
	GPS Observed	285485.155	2430806.868
	Difference	-0.025	0.108
82	Computed	285897.810	2444051.290
	GPS Observed	285897.884	2444051.272
	Difference	0.074	-0.018

Corner Number		Northing	Easting
83	Computed	286607.930	2465096.390
	GPS Observed	286607.827	2465096.379
	Difference	-0.103	-0.011
84	Computed	286966.810	2475689.150
	GPS Observed	286966.921	2475689.137
	Difference	0.111	-0.013
85	Computed	287597.490	2499429.900
	GPS Observed	287597.472	2499430.033
	Difference	-0.018	0.133
86	Computed	287705.950	2504707.170
	GPS Observed	287706.021	2504707.250
	Difference	0.071	0.080
87	Computed	288077.910	2544129.690
	GPS Observed	288077.821	2544129.579
	Difference	-0.089	-0.111
88	Computed	288087.480	2546777.450
	GPS Observed	288087.427	2546777.473
	Difference	-0.053	0.023
89	Computed	288527.700	2562676.480
	GPS Observed	288527.852	2562676.614
	Difference	0.152	0.134
90	Computed	288592.090	2565321.580
	GPS Observed	288592.275	2565321.749
	Difference	0.185	0.169
91	Computed	285378.790	2538951.690
	GPS Observed	285378.766	2538951.576
	Difference	-0.024	-0.114
92	Computed	285319.970	2523103.440
	GPS Observed	285319.968	2523103.487
	Difference	-0.002	0.047
93	Computed	284464.370	2481004.280
	GPS Observed	284464.283	2481004.188
	Difference	-0.087	-0.092
94	Computed	283727.330	2457171.610
	GPS Observed	283727.326	2457171.469
	Difference	-0.004	-0.141

Table 3 (continued)

Corner Number		Northing	Easting
95	Computed	283447.910	2449322.740
	GPS Observed	283448.019	2449322.842
	Difference	0.109	0.102
96	Computed	280798.240	2449320.560
	GPS Observed	280798.249	2449320.566
	Difference	0.009	0.006
97	Computed	280799.320	2449346.940
	GPS Observed	280799.364	2449347.024
	Difference	0.044	0.084
98	Computed	282671.650	2523165.290
	GPS Observed	282671.611	2523165.340
	Difference	-0.039	0.050
99	Computed	282711.530	2531065.180
	GPS Observed	282711.550	2531065.160
	Difference	0.020	-0.020
100	Computed	282722.810	2536345.530
	GPS Observed	282722.724	2536345.503
	Difference	-0.086	-0.027
101	Computed	282722.800	2536360.870
	GPS Observed	282722.752	2536360.894
	Difference	-0.048	0.024
102	Computed	282738.010	2538994.930
	GPS Observed	282737.962	2538994.880
	Difference	-0.048	-0.050
103	Computed	282784.420	2544229.870
	GPS Observed	282784.312	2544229.699
	Difference	-0.108	-0.171
104	Computed	282825.090	2549524.370
	GPS Observed	282825.011	2549524.229
	Difference	-0.079	-0.141
105	Computed	282919.400	2552167.870
	GPS Observed	282919.242	2552167.914
	Difference	-0.158	0.044
106	Computed	282921.000	2552216.800
	GPS Observed	282920.940	2552216.876
	Difference	-0.060	0.076
107	Computed	283083.490	2557427.600
	GPS Observed	283083.322	2557427.633
	Difference	-0.168	0.033
108	Computed	283085.050	2557477.220
	GPS Observed	283084.921	2557477.224
	Difference	-0.129	0.004
109	Computed	283166.840	2560065.170
	GPS Observed	283166.830	2560065.187
	Difference	-0.010	0.017
110	Computed	283168.300	2560115.590
	GPS Observed	283168.256	2560115.606
	Difference	-0.044	0.016
111	Computed	283243.610	2562703.670
	GPS Observed	283243.689	2562703.669
	Difference	0.079	-0.001
112	Computed	283287.100	2564417.200
	GPS Observed	283287.076	2564417.322
	Difference	-0.024	0.122
113	Computed	280047.570	2539087.230
	GPS Observed	280047.441	2539087.149
	Difference	-0.129	-0.081
114	Computed	280001.330	2523207.890
	GPS Observed	280001.310	2523208.000
	Difference	-0.020	0.110
115	Computed	279708.740	2510138.570
	GPS Observed	279708.786	2510138.554
	Difference	0.046	-0.016
116	Computed	279269.510	2491655.150
	GPS Observed	279269.424	2491655.127
	Difference	-0.086	-0.023
117	Computed	279091.210	2481178.690
	GPS Observed	279091.222	2481178.741
	Difference	0.012	0.051
118	Computed	274986.910	2433709.630
	GPS Observed	274986.942	2433709.614
	Difference	0.032	-0.016

Table 3 (continued)

Corner Number		Northing	Easting
119	Computed	275505.740	2452171.120
	GPS Observed	275505.672	2452171.111
	Difference	-0.068	-0.009
120	Computed	276699.090	2494375.620
	GPS Observed	276699.010	2494375.519
	Difference	-0.080	-0.101
121	Computed	276785.160	2497020.010
	GPS Observed	276785.013	2497019.969
	Difference	-0.147	-0.041
122	Computed	276861.530	2504949.320
	GPS Observed	276861.426	2504949.246
	Difference	-0.104	-0.074
123	Computed	277035.310	2510226.120
	GPS Observed	277035.335	2510226.106
	Difference	0.025	-0.014
124	Computed	277246.080	2515505.920
	GPS Observed	277246.102	2515506.040
	Difference	0.022	0.120
125	Computed	277437.080	2544443.230
	GPS Observed	277436.984	2544443.100
	Difference	-0.096	-0.130
126	Computed	277698.940	2560301.200
	GPS Observed	277698.772	2560301.205
	Difference	-0.168	0.005
127	Computed	277793.160	2562933.830
	GPS Observed	277793.024	2562933.924
	Difference	-0.136	0.094
128	Computed	275153.730	2563024.480
	GPS Observed	275153.846	2563024.512
	Difference	0.116	0.032
129	Computed	274775.170	2547172.980
	GPS Observed	274775.126	2547172.874
	Difference	-0.044	-0.106
130	Computed	274736.300	2531328.380
	GPS Observed	274736.117	2531328.278
	Difference	-0.183	-0.102
131 ***	Computed	274718.670	2523345.400
	GPS Observed	274718.558	2523345.447
	Difference	-0.112	0.047
132	Computed	273544.570	2476008.990
	GPS Observed	273544.515	2476009.011
	Difference	-0.055	0.021
133	Computed	273159.360	2460173.140
	GPS Observed	273159.544	2460173.238
	Difference	0.184	0.098
134	Computed	272413.930	2436444.360
	GPS Observed	272413.779	2436444.372
	Difference	-0.151	0.012
135	Computed	272215.000	2428534.180
	GPS Observed	272214.869	2428534.152
	Difference	-0.131	-0.028
136	Computed	270498.920	2465527.750
	GPS Observed	270498.934	2465527.877
	Difference	0.014	0.127
137	Computed	271127.530	2481392.470
	GPS Observed	271127.582	2481392.481
	Difference	0.052	0.011
138	Computed	271419.460	2494525.810
	GPS Observed	271419.490	2494525.741
	Difference	0.030	-0.069
139	Computed	269717.440	2557940.790
	GPS Observed	269717.275	2557940.798
	Difference	-0.165	0.008
140	Computed	269557.240	2549987.930
	GPS Observed	269557.361	2549988.007
	Difference	0.121	0.077
141	Computed	269470.390	2536791.820
	GPS Observed	269470.487	2536791.747
	Difference	0.097	-0.073
142	Computed	269418.360	2523526.590
	GPS Observed	269418.302	2523526.542
	Difference	-0.058	-0.048

Table 3 (continued)

Corner Number		Northing	Easting
143	Computed	269219.620	2513085.300
	GPS Observed	269219.647	2513085.190
	Difference	0.027	-0.110
144	Computed	268659.500	2489313.700
	GPS Observed	268659.560	2489313.704
	Difference	0.060	0.004
145	Computed	267292.600	2441923.330
	GPS Observed	267292.468	2441923.335
	Difference	-0.132	0.005
146	Computed	266881.800	2426079.090
	GPS Observed	266881.794	2426079.144
	Difference	-0.006	0.054
147	Computed	266823.790	2423399.650
	GPS Observed	266823.759	2423399.677
	Difference	-0.031	0.027
148	Computed	264792.690	2447267.510
	GPS Observed	264792.602	2447267.640
	Difference	-0.088	0.130
149	Computed	265230.330	2460387.660
	GPS Observed	265230.240	2460387.697
	Difference	-0.090	0.037
150	Computed	265231.400	2465711.190
	GPS Observed	265231.368	2465711.330
	Difference	-0.032	0.140
151	Computed	265497.990	2473581.950
	GPS Observed	265498.041	2473582.005
	Difference	0.051	0.055
152	Computed	265720.490	2478855.270
	GPS Observed	265720.510	2478855.330
	Difference	0.020	0.060
153	Computed	266193.080	2497291.350
	GPS Observed	266193.066	2497291.225
	Difference	-0.014	-0.125
154	Computed	266221.620	2499963.300
	GPS Observed	266221.761	2499963.234
	Difference	0.141	-0.066

Corner Number		Northing	Easting
155	Computed	266363.970	2507858.360
	GPS Observed	266363.810	2507858.365
	Difference	-0.160	0.005
156	Computed	266855.540	2542162.700
	GPS Observed	266855.615	2542162.583
	Difference	0.075	-0.117
157	Computed	266903.790	2552739.800
	GPS Observed	266903.830	2552739.641
	Difference	0.040	-0.159
158	Computed	264434.110	2558113.830
	GPS Observed	264434.052	2558113.951
	Difference	-0.058	0.121
159	Computed	264209.930	2547535.800
	GPS Observed	264209.856	2547535.687
	Difference	-0.074	-0.113
160	Computed	264172.000	2531623.450
	GPS Observed	264172.081	2531623.538
	Difference	0.081	0.088
161	Computed	264168.840	2528973.110
	GPS Observed	264168.917	2528973.085
	Difference	0.077	-0.025
162	Computed	263934.800	2513230.600
	GPS Observed	263934.767	2513230.535
	Difference	-0.033	-0.065
163	Computed	263187.920	2481558.180
	GPS Observed	263187.981	2481558.211
	Difference	0.061	0.031
164	Computed	259023.430	2428983.690
	GPS Observed	259023.351	2428983.758
	Difference	-0.079	0.068
165	Computed	259944.360	2460538.840
	GPS Observed	259944.337	2460538.887
	Difference	-0.023	0.047
166	Computed	260849.500	2494791.640
	GPS Observed	260849.626	2494791.670
	Difference	0.126	0.030

Table 3 (continued)

Corner Number		Northing	Easting
167	Computed	261043.240	2505370.290
	GPS Observed	261043.185	2505370.141
	Difference	-0.055	-0.149
168	Computed	261304.760	2513296.990
	GPS Observed	261304.636	2513296.953
	Difference	-0.124	-0.037
169	Computed	257669.910	2476430.050
	GPS Observed	257669.923	2476429.917
	Difference	0.013	-0.133
170	Computed	257134.230	2455446.420
	GPS Observed	257134.241	2455446.363
	Difference	0.011	-0.057
171	Computed	256806.630	2444909.060
	GPS Observed	256806.712	2444908.909
	Difference	0.082	-0.151
172	Computed	254341.620	2450296.460
	GPS Observed	254341.780	2450296.391
	Difference	0.160	-0.069
173	Computed	254578.950	2458064.970
	GPS Observed	254579.079	2458064.943
	Difference	0.129	-0.027
174	Computed	254684.900	2463356.320
	GPS Observed	254684.791	2463356.176
	Difference	-0.109	-0.144
175	Computed	254863.830	2471260.760
	GPS Observed	254863.886	2471260.864
	Difference	0.056	0.104
176	Computed	255234.220	2481831.310
	GPS Observed	255234.061	2481831.150
	Difference	-0.159	-0.160
177	Computed	255601.200	2497586.350
	GPS Observed	255601.365	2497586.235
	Difference	0.165	-0.115
178	Computed	255828.570	2508151.830
	GPS Observed	255828.701	2508151.883
	Difference	0.131	0.053
179	Computed	256132.680	2521275.070
	GPS Observed	256132.663	2521275.203
	Difference	-0.017	0.133
180	Computed	256155.070	2523906.490
	GPS Observed	256155.065	2523906.589
	Difference	-0.005	0.099
181	Computed	256222.080	2529240.210
	GPS Observed	256222.138	2529240.059
	Difference	0.058	-0.151
182	Computed	256282.620	2539821.110
	GPS Observed	256282.748	2539821.122
	Difference	0.128	0.012
183	Computed	256296.070	2542460.910
	GPS Observed	256296.182	2542460.980
	Difference	0.112	0.070
184	Computed	256280.360	2547745.260
	GPS Observed	256280.488	2547745.395
	Difference	0.128	0.135
185	Computed	256312.120	2553038.290
	GPS Observed	256311.976	2553038.284
	Difference	-0.144	-0.006
186	Computed	256488.550	2558333.820
	GPS Observed	256488.544	2558333.739
	Difference	-0.006	-0.081
187	Computed	251880.650	2455631.930
	GPS Observed	251880.788	2455631.841
	Difference	0.138	-0.089
188	Computed	251241.400	2434500.620
	GPS Observed	251241.454	2434500.441
	Difference	0.054	-0.179
189	Computed	251178.580	2431859.560
	GPS Observed	251178.496	2431859.431
	Difference	-0.084	-0.129
190	Computed	248423.860	2426646.270
	GPS Observed	248423.879	2426646.220
	Difference	0.019	-0.050

Table 3 (continued)

Corner Number		Northing	Easting
191	Computed	248539.750	2431931.670
	GPS Observed	248539.725	2431931.612
	Difference	-0.025	-0.058
192	Computed	243486.940	2440001.020
	GPS Observed	243486.794	2440000.921
	Difference	-0.146	-0.099
193	Computed	237883.970	2426990.190
	GPS Observed	237884.116	2426990.166
	Difference	0.146	-0.024
194	Computed	235575.320	2440190.400
	GPS Observed	235575.251	2440190.226
	Difference	-0.069	-0.174

Corner Number		Northing	Easting
195	Computed	235735.210	2445500.120
	GPS Observed	235735.163	2445500.035
	Difference	-0.047	-0.085
196	Computed	233106.460	2445546.090
	GPS Observed	233106.521	2445546.000
	Difference	0.061	-0.090
197	Computed	230261.170	2437702.680
	GPS Observed	230261.154	2437702.561
	Difference	-0.016	-0.119
198	Computed	230625.640	2450887.200
	GPS Observed	230625.676	2450887.137
	Difference	0.036	-0.063

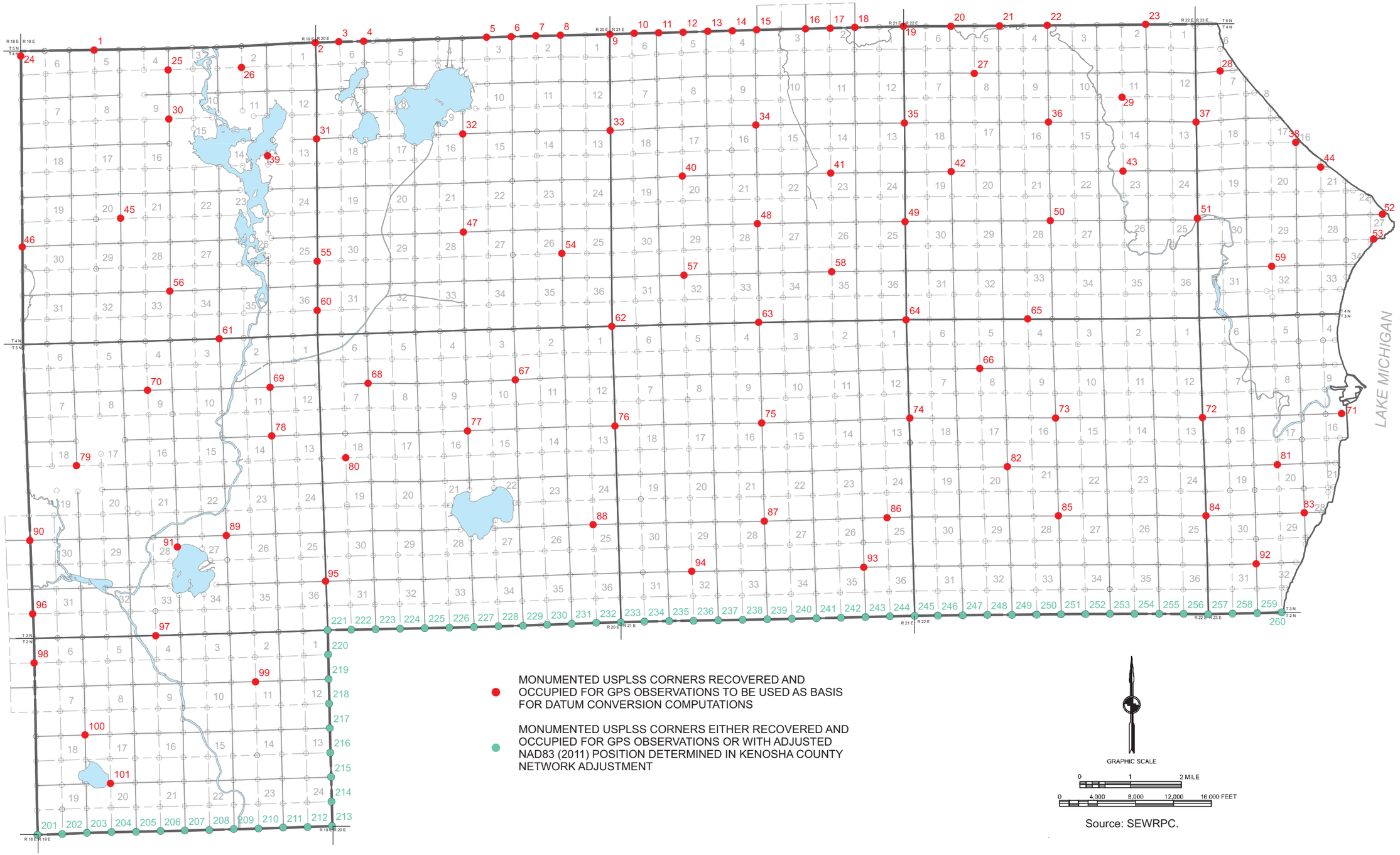
CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 3

	Northing	Easting
Sum of Squared Differences	1.693	1.610
Average	-0.008	-0.002
Minimum Difference.....	-0.183	-0.179
Maximum Difference.....	0.188	0.173
RMSE	0.092	0.090
$RMSE_{min}$ / $RMSE_{max}$	0.975	
NSSDA 95% RMSE Accuracy $_r$	0.224	
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 RACINE COUNTY SHOWING U.S. PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO DETERMINE NAD83 (2011) COORDINATES AS BASIS FOR DATUM CONVERSION COMPUTATIONS



Source: SEWRPC.

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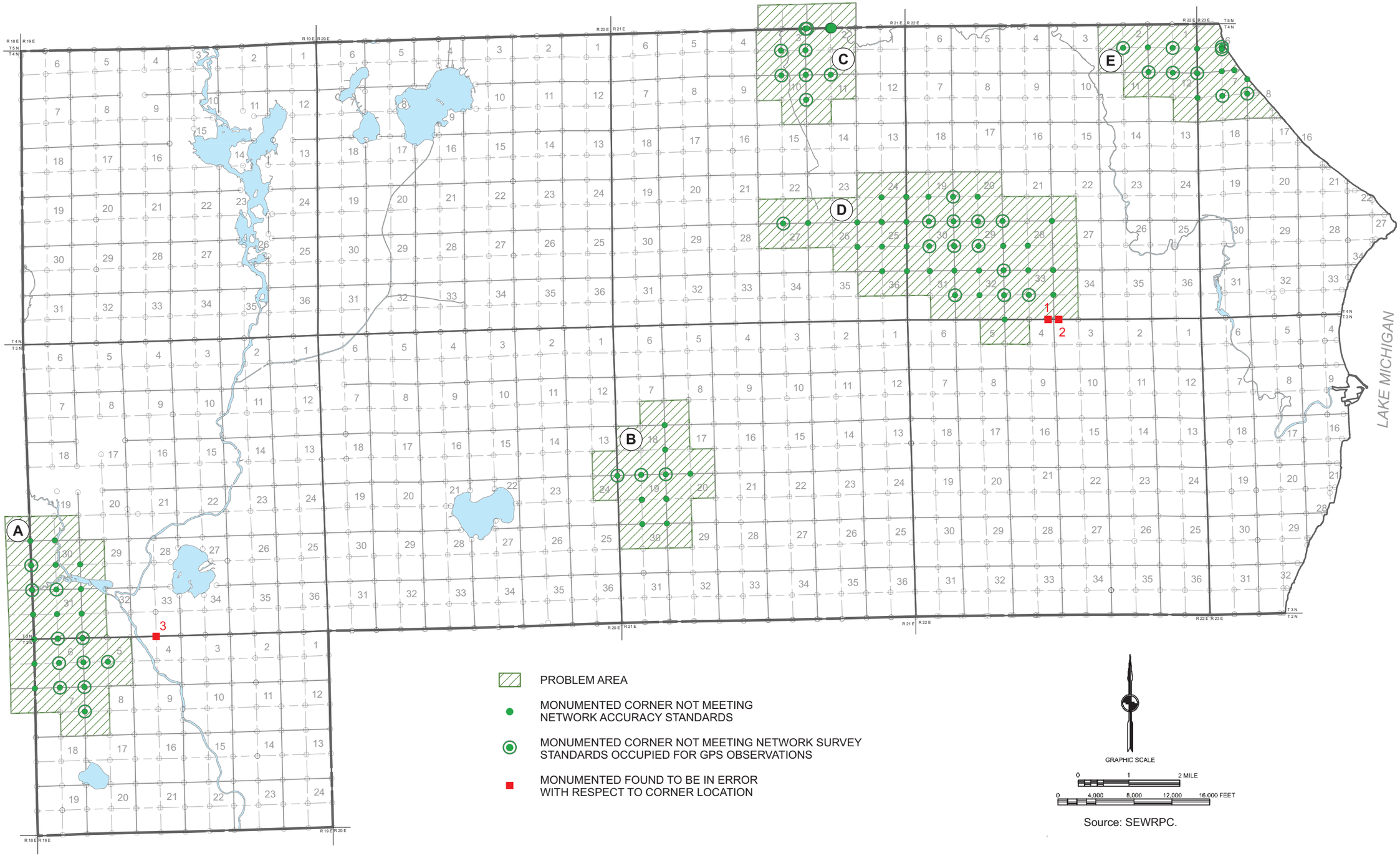
Figure 2

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



Source: SEWRPC.

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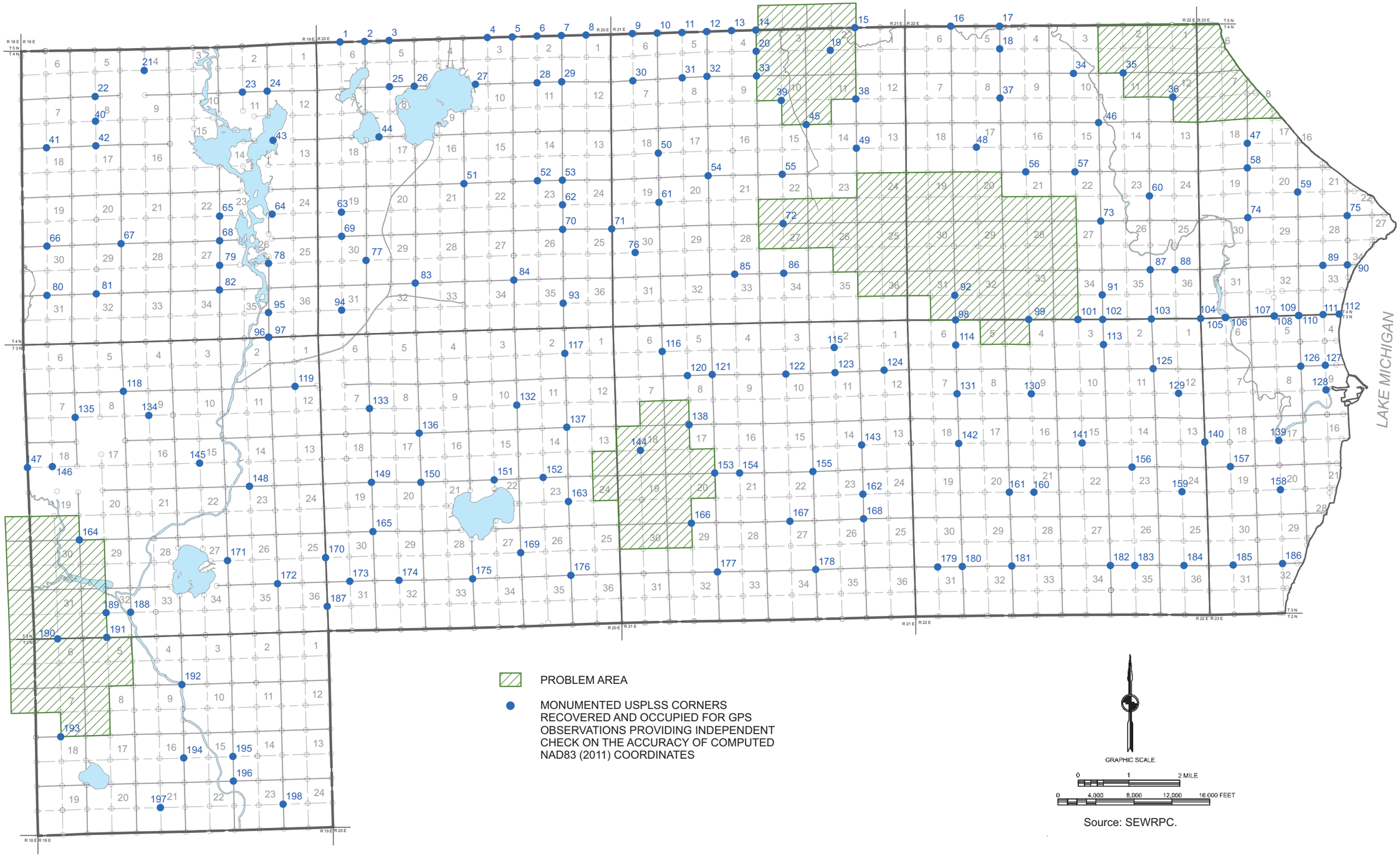
Figure 3

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



Source: SEWRPC.

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Figure 4

SAMPLE DOSSIER

RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

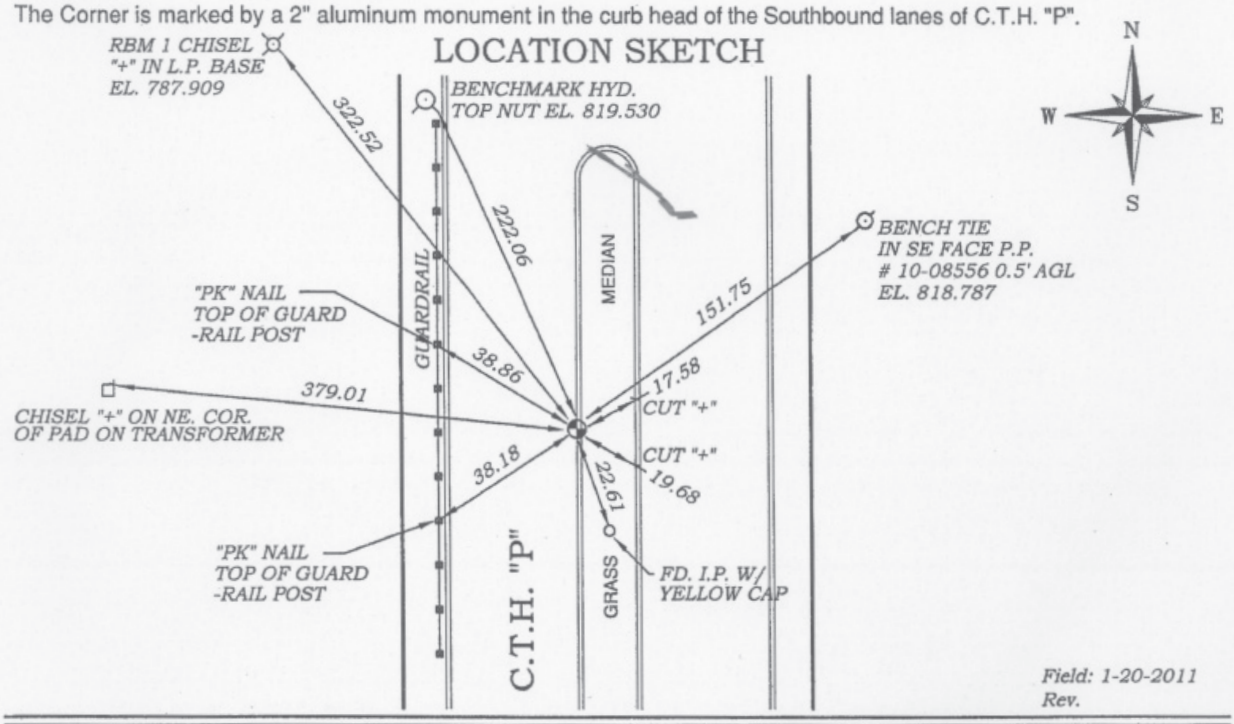
U.S. PUBLIC LAND SURVEY CORNER 6|5 / 6|5 T 02 N, R 19 E, RACINE COUNTY, WISCONSIN

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: SEWRPC 2017	HOR. CONTROL: SEWRPC 2017
VERT. CONTROL: NIELSEN MADSEN & BARBER, S.C. 2011	VERT. CONTROL:
NORTHING: 245,862.42 USFT	NORTHING: 245,873.10 USFT
EASTING: 2,460,964.60 USFT	EASTING: 2,429,427.68 USFT
ELEVATION: 823.804 FT	ELEVATION: FT
HOR. ACCURACY: 3rd ORDER, CLASS I (COMPUTED)	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

The Corner is marked by a 2" aluminum monument in the curb head of the Southbound lanes of C.T.H. "P".

LOCATION SKETCH



Field: 1-20-2011
Rev.

SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN } S.S.
RACINE COUNTY }

I hereby certify that following road reconstruction I set a 2" aluminum monument in the curb head of the median to mark this corner, replacing a cast iron monument with a brass cap set in June, 1971 by John H. Nielsen (S-338), whose location was based on reference ties on file with Racine County Highway Department; which replaced a ¾" diameter iron stake, and 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
MARK R. MADSEN
S-2271
RACINE, WI
LAND SURVEYOR

DATE OF SURVEY: 01-20-2011

Mark R. Madsen
REGISTERED LAND SURVEYOR

S- 2271

Form designed by: SEWRPC
Prepared by: Racine County Surveyor

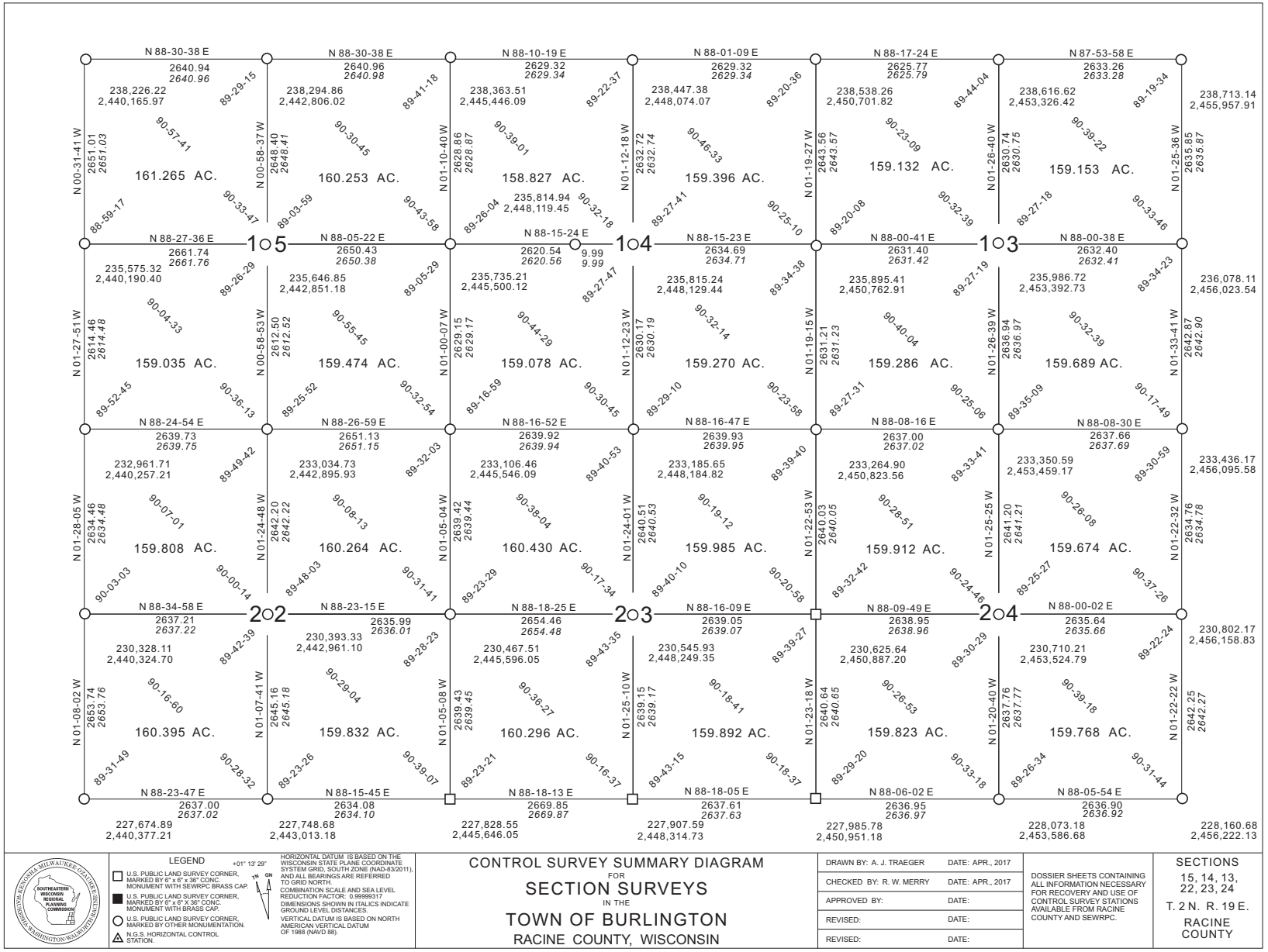
FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION (SEWRPC)
CERTIFICATION APPLIES ONLY TO THE LOCATION SKETCH AND SURVEYOR AFFIDAVIT

02190160 16 –

Source: SEWRPC.

Figure 5

SAMPLE CSSD



LEGEND

+01° 13' 29"

- U.S. PUBLIC LAND SURVEY CORNER, MARKED BY 6" x 6" x 36" CONC. MONUMENT WITH SEWRPC BRASS CAP.
- U.S. PUBLIC LAND SURVEY CORNER, MARKED BY 6" x 6" X 36" CONC. MONUMENT WITH BRASS CAP.
- U.S. PUBLIC LAND SURVEY CORNER, MARKED BY OTHER MONUMENTATION.
- N.G.S. HORIZONTAL CONTROL STATION.

HORIZONTAL DATUM IS BASED ON THE WISCONSIN STATE PLANE COORDINATE SYSTEM GRID, SOUTH ZONE (NAD-83/2011), AND ALL BEARINGS ARE REFERRED TO GRID NORTH.

COMBINATION SCALE AND SEA LEVEL REDUCTION FACTOR: 0.99999317

DIMENSIONS SHOWN IN ITALICS INDICATE GROUND LEVEL DISTANCES.

VERTICAL DATUM IS BASED ON NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88).

CONTROL SURVEY SUMMARY DIAGRAM
FOR
SECTION SURVEYS
IN THE
TOWN OF BURLINGTON
RACINE COUNTY, WISCONSIN

DRAWN BY: A. J. TRAEGER	DATE: APR., 2017
CHECKED BY: R. W. MERRY	DATE: APR., 2017
APPROVED BY:	DATE:
REVISED:	DATE:
REVISED:	DATE:

DOSSIER SHEETS CONTAINING ALL INFORMATION NECESSARY FOR RECOVERY AND USE OF CONTROL SURVEY STATIONS AVAILABLE FROM RACINE COUNTY AND SEWRPC.

SECTIONS
15, 14, 13,
22, 23, 24
T. 2 N. R. 19 E.
RACINE
COUNTY

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

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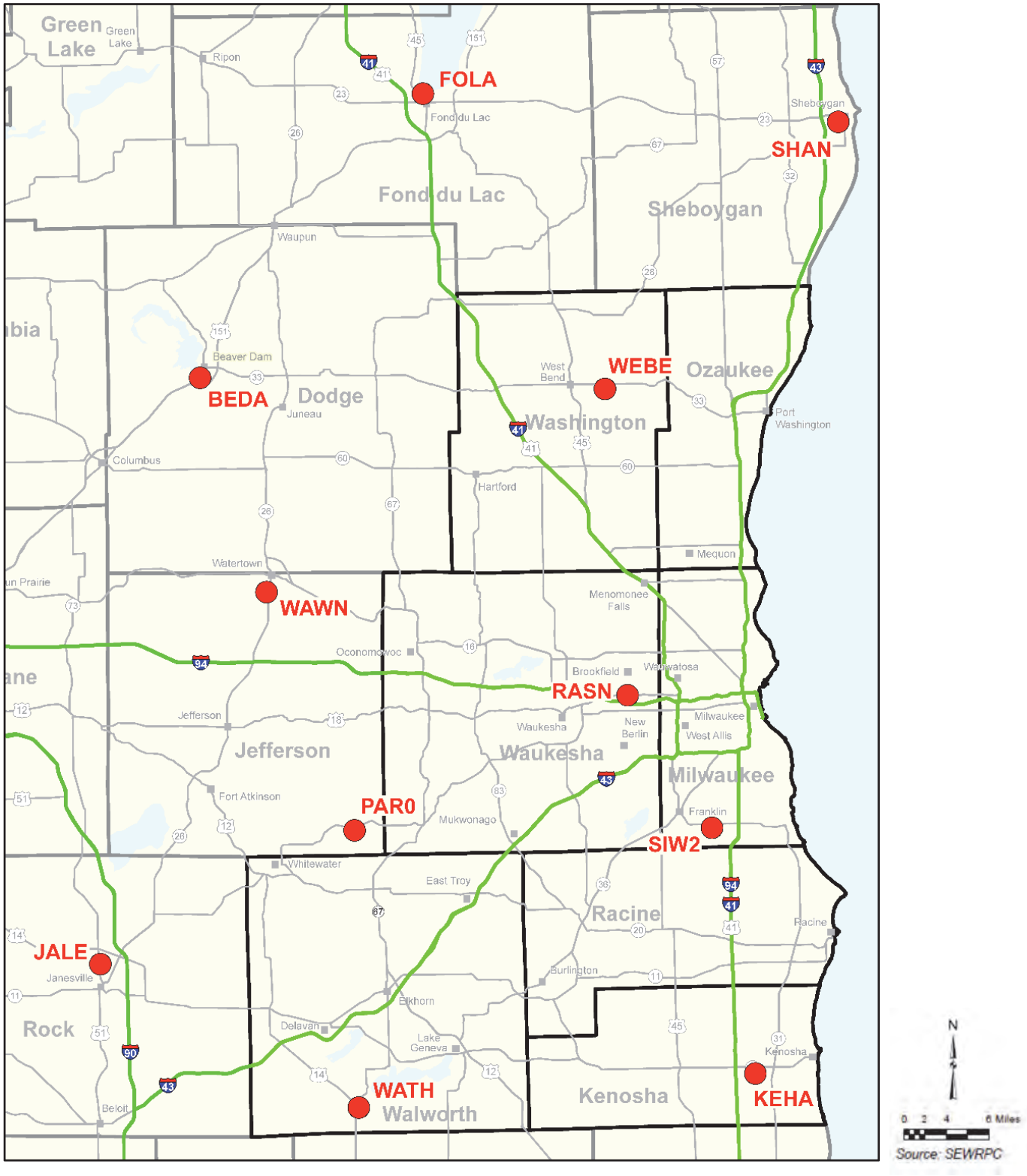
[1]*The term "least squares adjustment" refers to a mathematical procedure based on the theory of probability that derives the statistically most likely coordinate location of points defined by multiple measurements in a network. Moreover, a least squares adjustment defines a best-fit solution for weighed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

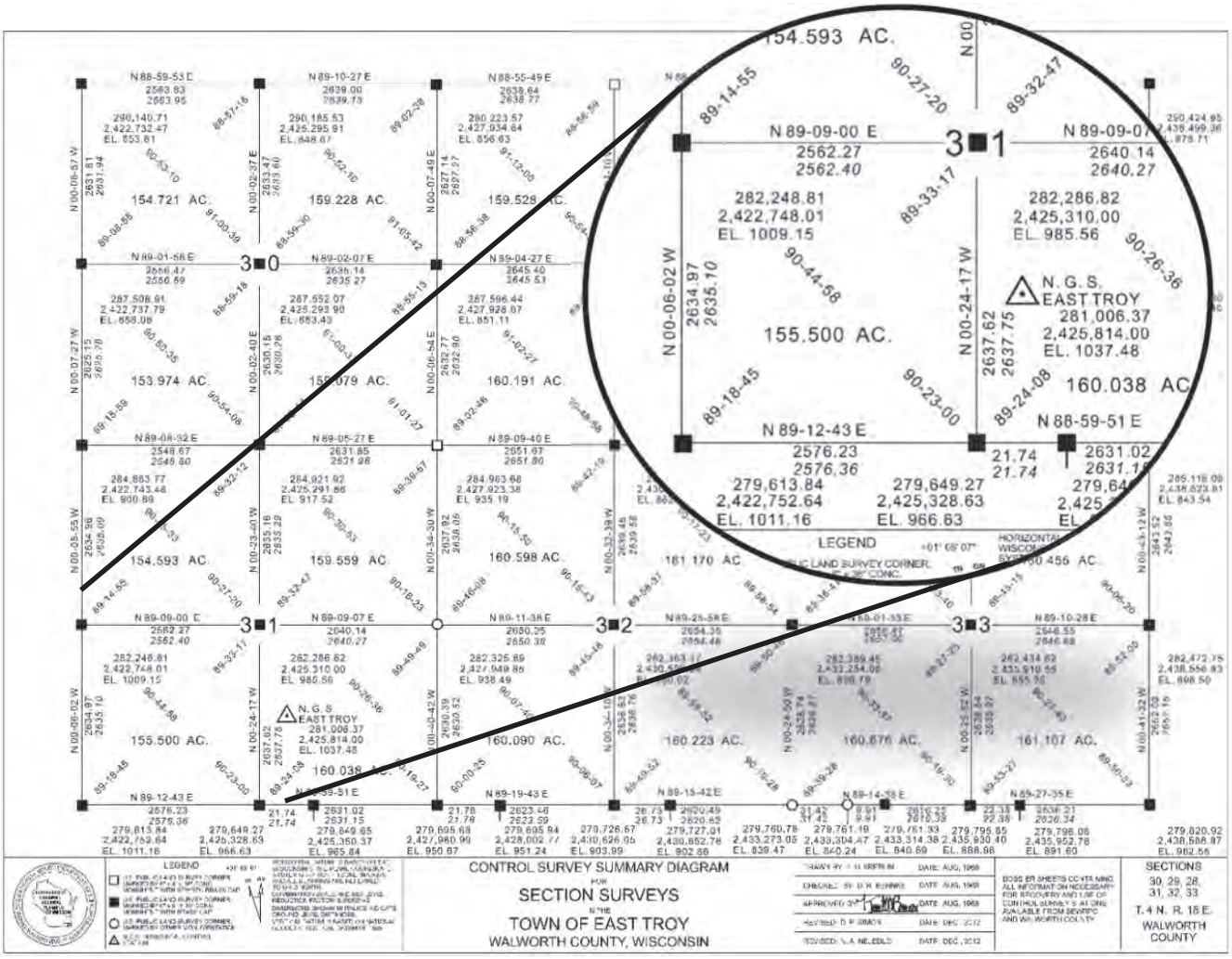
Computations

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).

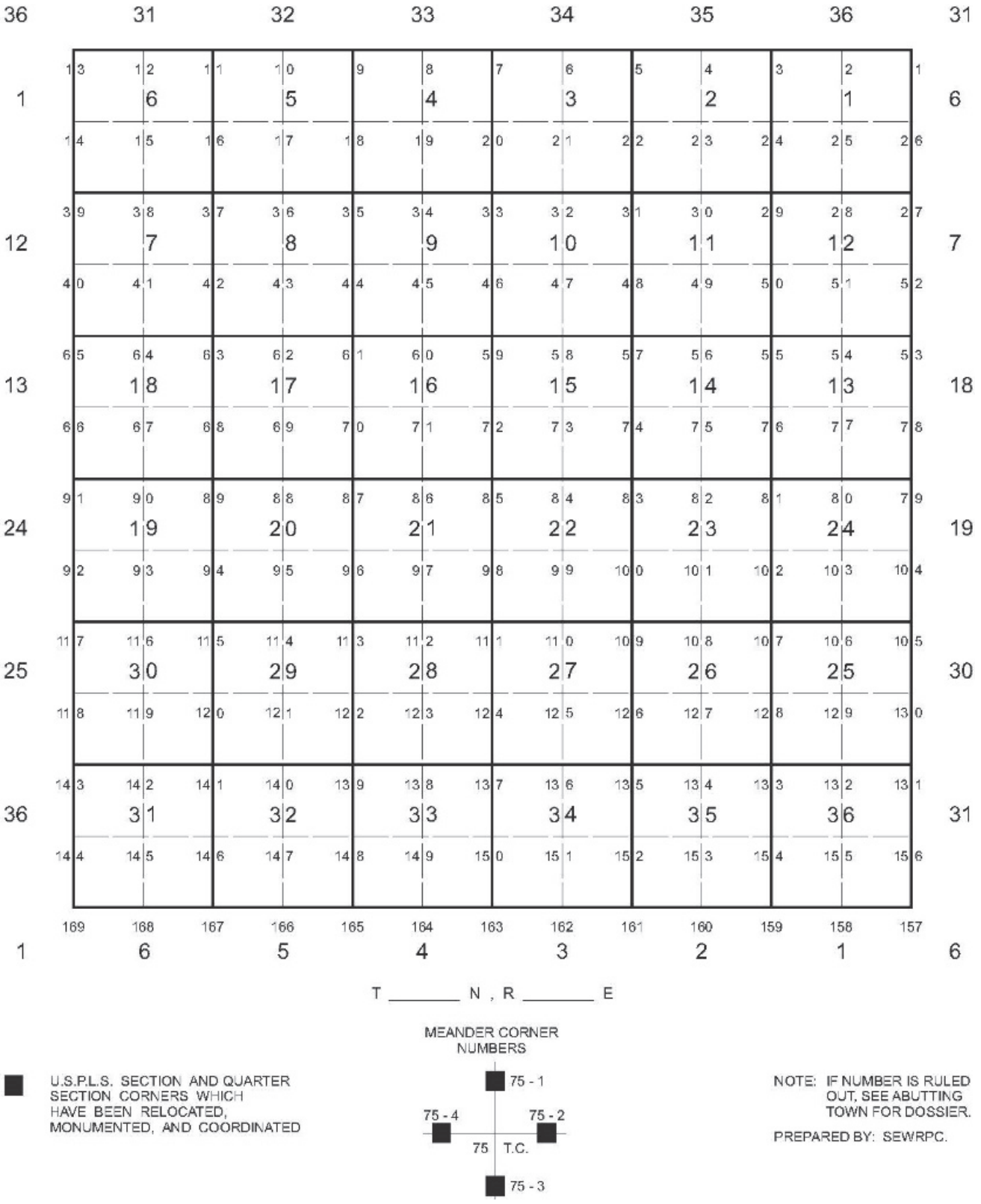
CONTROL SURVEY STATION NUMBERING

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



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.

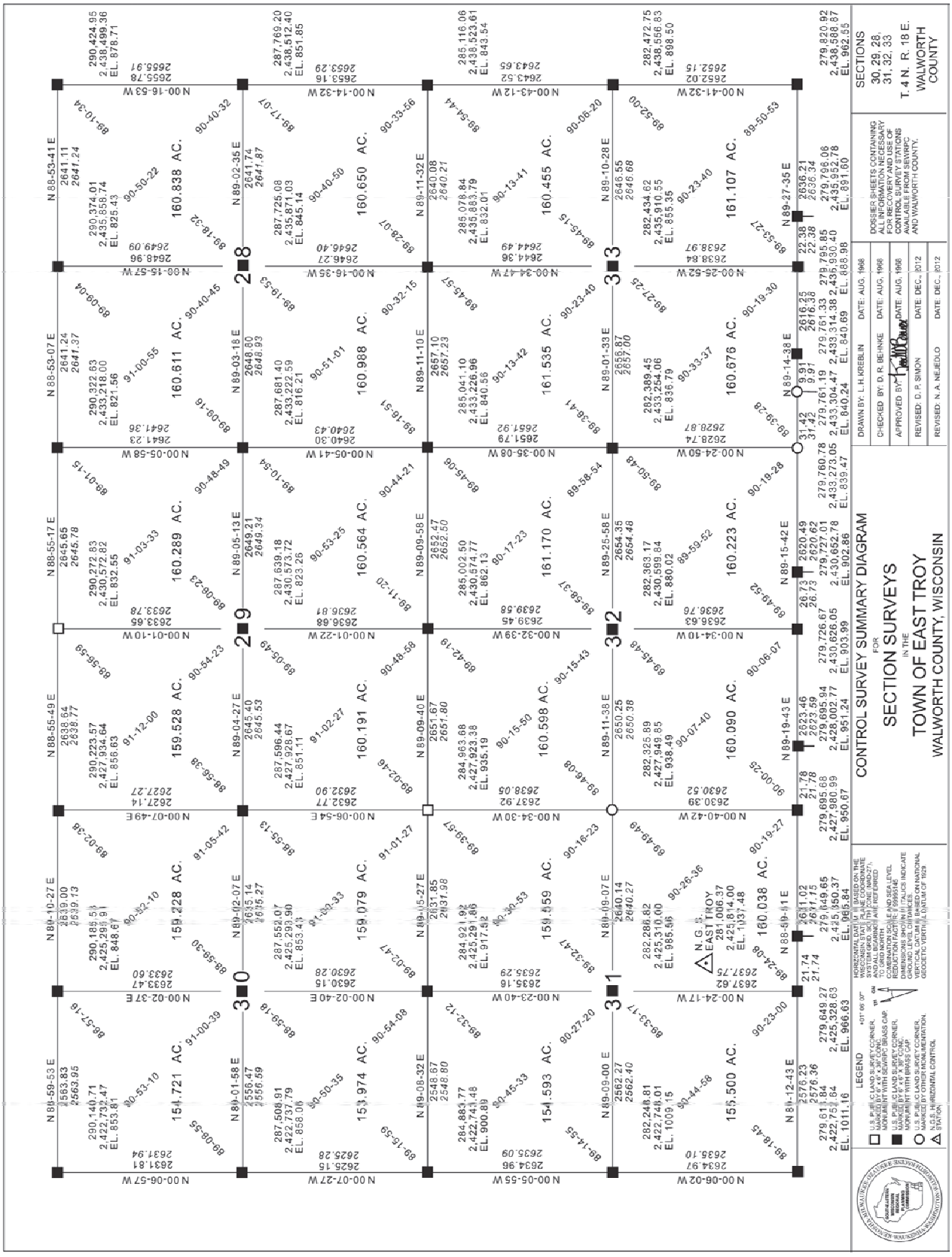
Since the completion of SEWRPC Technical Report No. 35, the Wisconsin Department of Transportation (WisDOT) in conjunction with NGS completed the Wisconsin Height Modernization Program (WI-HMP) within the Region. This program provided high-order orthometric height data on a carefully distributed network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

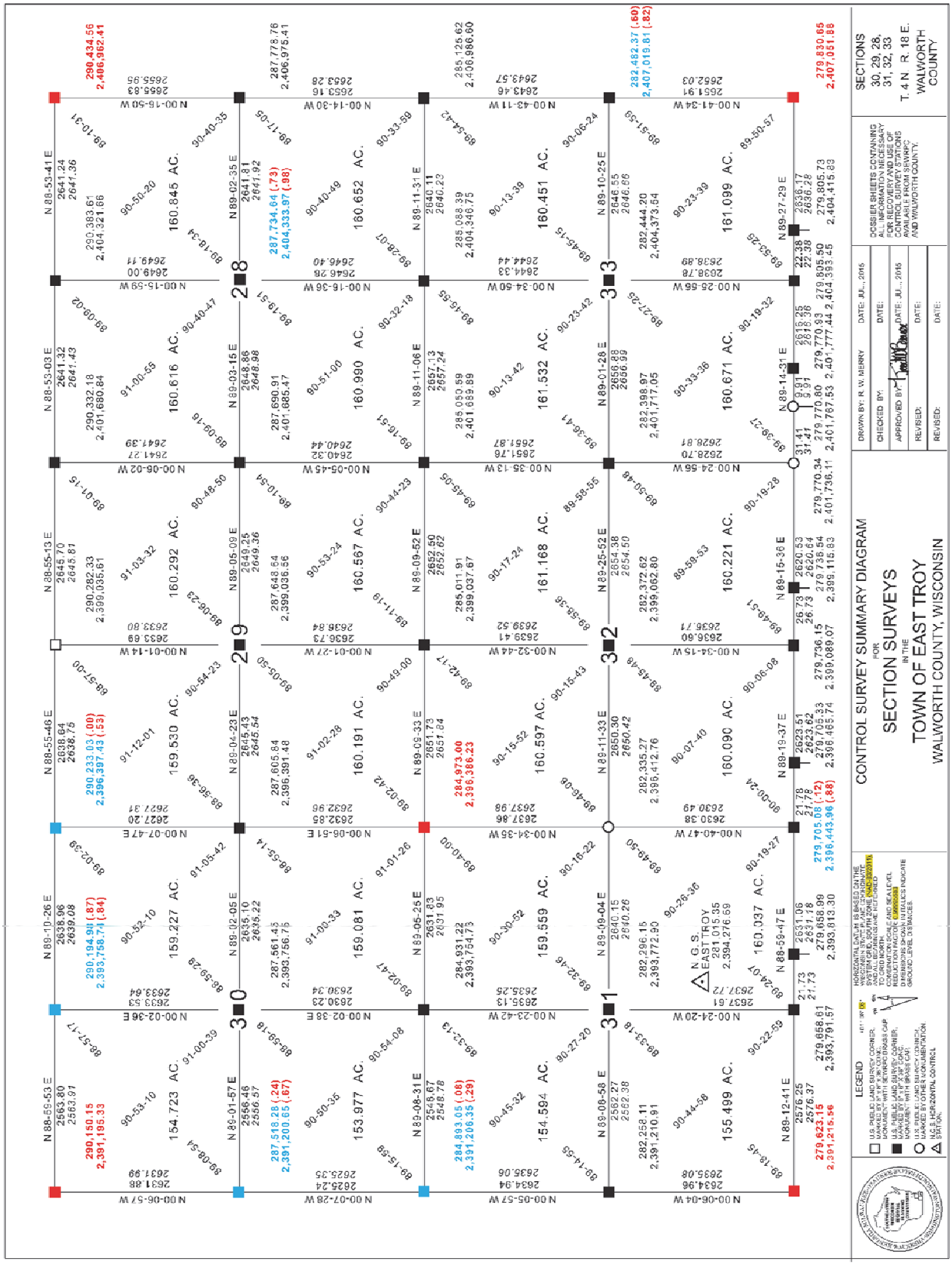
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 27



Source: SEWRPC.

Figure 5

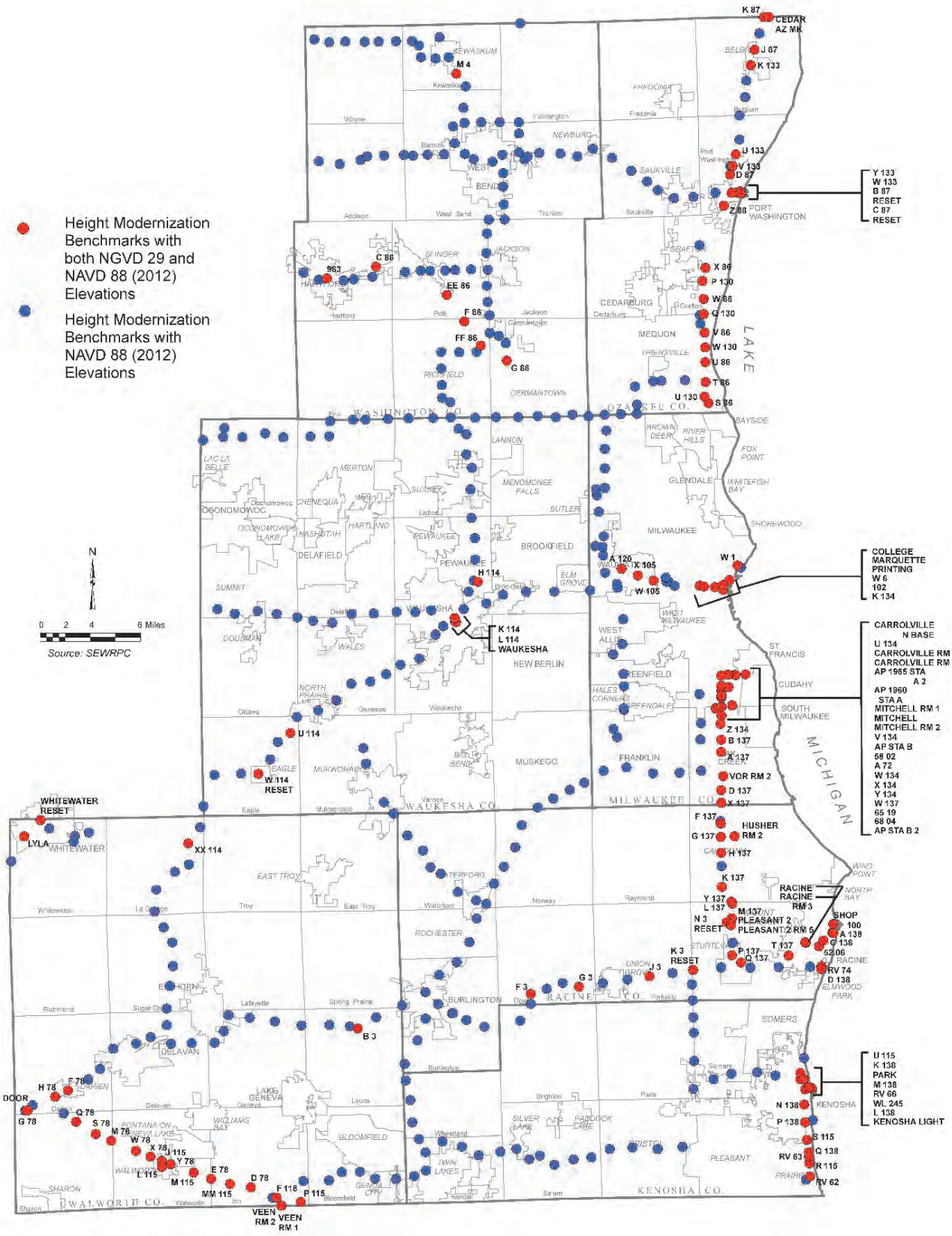
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 83 (2011)



Source: SEWRPC.

Figure 6

WISCONSIN HEIGHT MODERNIZATION BENCH MARKS WITHIN THE SOUTHEASTERN WISCONSIN REGION



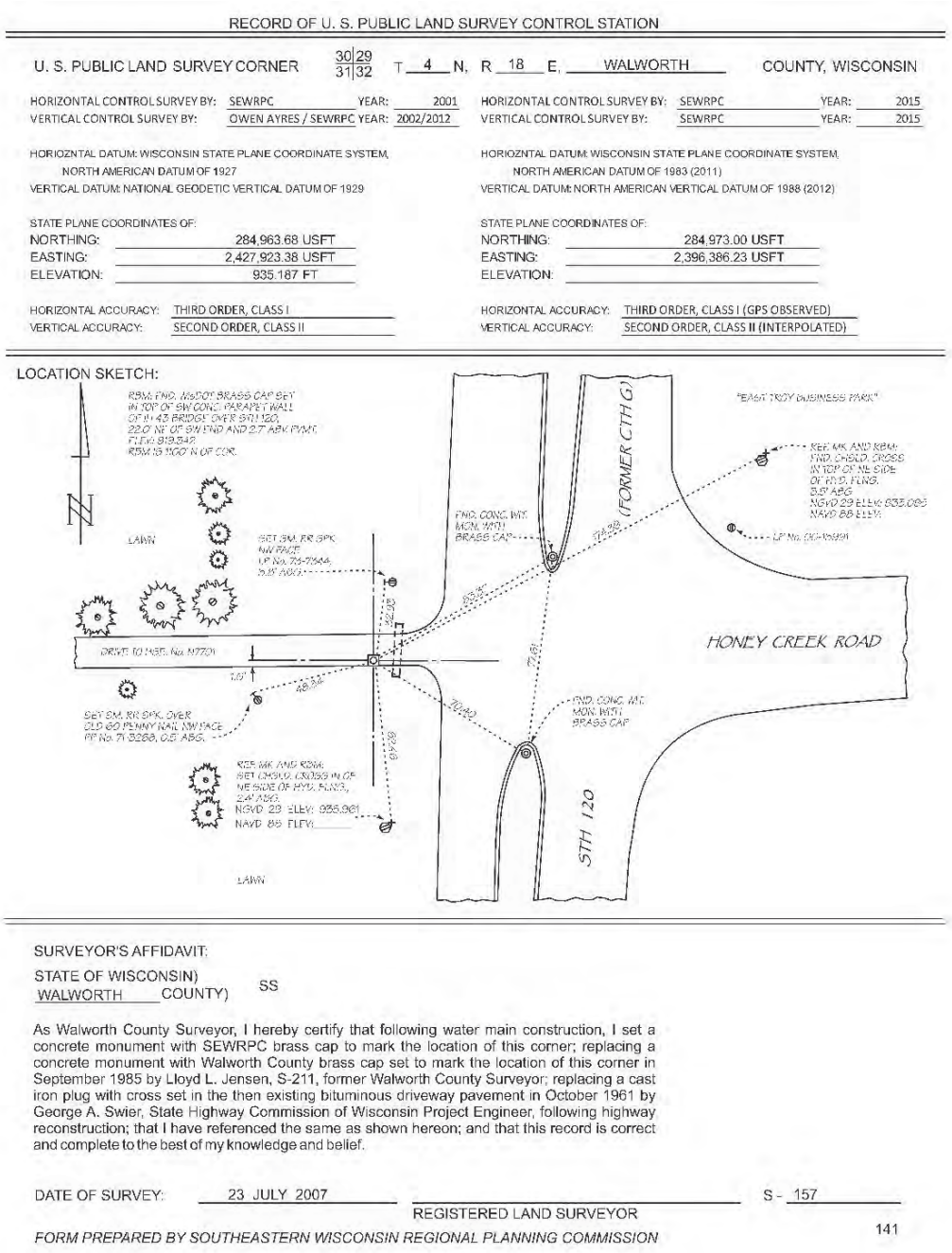
Source: SEWRPC.

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) SS
WALWORTH COUNTY)

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 _____ S - 157
REGISTERED LAND SURVEYOR

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

141

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.