MEMORANDUM REPORT NO. 200

COMPARISON OF THE RELATIONSHIP OF ALTERNATIVE 2010 ORTHOPHOTOGRAPHS FOR MILWAUKEE COUNTY TO NATIONAL MAP ACCURACY STANDARDS

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COMPARISON OF THE RELATIONSHIP OF ALTERNATIVE 2010 ORTHOPHOTOGRAPHS FOR MILWAUKEE COUNTY TO NATIONAL MAP ACCURACY STANDARDS

INTRODUCTION

Subject to available funding, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) sponsors at five year intervals a joint effort to obtain new orthophotography for the seven-county southeastern Wisconsin Region consisting of the Counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington and Waukesha. Such orthophotography is useful to all levels, units, and agencies of government as well as private sector interests. The 2010 orthophotography project was jointly sponsored and funded by the U.S. Geological Survey (USGS), the U.S. Department of Transportation, the seven constituent counties of the Region, the Cities of Mequon and Racine, and the Commission. Information relative to the funding arrangements and product deliverables for the 2010 regional program is included in Appendix A. The Commission worked closely with the land information officers of the seven counties concerned in establishing the cooperative effort. Based upon the qualifications based selection (QBS) process jointly administered by regional planning commissions within Wisconsin, the firm of AeroMetric, Inc. of Sheboygan, Wisconsin, was selected to provide the professional services necessary to prepare the 2010 orthophotography products for the Region.

As arrangements were being completed for the joint program, Milwaukee County, through its Milwaukee County Automated Mapping and Land Information System (MCAMLIS) Project Manager, requested that, in lieu of conventionally prepared orthophotography, consideration be given to utilizing available Federal funding to support within that County the acquisition of a newly announced orthophotography product by Pictometry International Corp. with the brand name AccuPlus. In ensuing interagency discussions concerning this request, it was determined that the AccuPlus product had not yet been deemed to be eligible for funding by the USGS, making that product categorically ineligible for the jointly funded Commission project. In order for the Commission to meet its own product acquisition standards, as well as its commitments to the USGS, the AccuPlus product could not, therefore, be substituted for the conventional orthophotography product to be prepared by AeroMetric and demonstrated to be able to meet National Map Accuracy Standards.[1] Pictometry International Corp. markets the new AccuPlus product in conjunction with its more mature product of oblique aerial photographs, a product that Milwaukee County had previously acquired and desires to keep up-to-date at periodic intervals.

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[1]*The standard set of Urban Area Orthophotography Rectified Imagery Specifications issued by the National Geospatial – Intelligence Agency (NGA) and provided to SEWRPC by the USGS provides that the horizontal accuracy of orthorectified imagery shall not exceed 3-meter Root Mean Square Error (RMSE) XY or 2.12 meter RMSE X or Y. In the seven-county Southeastern Wisconsin Region this particular specification was modified for contract purposes to refer instead to, in the case of Milwaukee County, National Map Accuracy Standards for 1 inch equals 100 feet scale mapping, a standard more stringent than the NGA standard.*

Further discussions with MCAMLIS staff led to a determination to fund both the conventional and the AccuPlus orthophotography products for Milwaukee County in 2010. This would permit the Commission to meet its own product standards and its obligations to the USGS; allow users to comparatively evaluate the two orthophotography products; and allow for a determination as to whether or not the AccuPlus product meets National Map Accuracy Standards at the desired scale of 1 inch equals 100 feet. It was believed that this process would be helpful not only to Milwaukee County, but to other county and local governments in the Region who in future years may wish to consider this alternative orthophotography product in conjunction with the acquisition of oblique photography. To effect this proposal, MCAMLIS agreed to fund its share of the basic regional 12-inch pixel orthophotography product, the local cost share associated with upgrading to a 6-inch pixel conventional orthophotography product, and the local cost share associated with obtaining the 6-inch pixel AccuPlus product. It was further agreed that the Commission would carry out a comparative evaluation of the two products concerned, with particular attention to the ability of both products to meet National Map Accuracy Standards. This report documents the results of the evaluation project.

PROJECT OBJECTIVES

The comparative evaluation project had the following two objectives:

1. To determine whether or not the conventional orthophotography product—produced by AeroMetric, Inc.—and the AccuPlus orthophotography product—produced by Pictometry International Corp.—for Milwaukee County in 2010 meet National Map Accuracy Standards at a scale of 1 inch equals 100 feet.
2. To establish ongoing arrangements whereby interested individuals would be able to view the two 2010 orthophotography products prepared for Milwaukee County, gain information about the technical processes used in producing the two sets of products and the relative costs associated with the two products, and evaluate for themselves the spectral quality of the two products.

OVERSIGHT COMMITTEE

To oversee the 2010 regional orthophotography evaluation project, the Commission, in accordance with its long-established practice, created a 12-member Technical Advisory Committee, the membership of which is listed on the inside front cover of this report. The Committee included representatives from the two firms that produced the orthophotography products being evaluated—Pictometry International Corp. and AeroMetric, Inc.—the Milwaukee County Surveyor, MCAMLIS, two land information officers from other counties in the southeastern Wisconsin Region, the Wisconsin Department of Transportation, the U.S. Geological Survey, and the Commission itself. The Committee was charged with reviewing and approving the process to be followed in undertaking the evaluation; for reviewing and commenting on the results of the evaluation; and for reviewing and approving this report. In discharging its responsibilities, the Committee met twice to review SEWRPC staff work.

EVALUATION PROCESS

The first objective of the comparative evaluation project was to determine whether or not the conventional and alternative orthophotography products concerned meet National Map Accuracy Standards at a scale of 1 inch equals 100 feet. The evaluation was conducted by selecting readily identifiable "picture points" on the two sets of orthophotographs concerned; determining the State Plane Coordinate values of the points by field survey; comparing the coordinate values of each point as determined from the orthophotographs by geographic information software with the coordinate values determined by field survey; and using the differential values obtained in the comparison to compute the deviation of each point from its field-defined location.

The National Map Accuracy Standards (NMAS) were selected as the basis for the evaluation, such standards being applied at a "publication" scale of 1 inch equals 100 feet for the 6-inch pixel orthophotography products that were produced. The Standards require that 90 percent of the positions of well-defined points as determined from the orthophotographs be within 3.3 feet of their correct position as determined by field measurement. The selection of NMAS for this project—as opposed to other recognized positional accuracy standards—relates to their simplicity, practicality, and long history of use in southeastern Wisconsin in developing the key foundational elements of the parcel-based land information systems being created within the Region.[2] The NMAS are reproduced in Appendix B.

It is recognized that an evaluation of the two orthophotography products also could be made with respect to spectral quality. That evaluation, however, would be largely subjective, and such an evaluation was, therefore, not included in the project. Rather, it was determined interested potential users would be afforded an opportunity to ascertain which of the two products, in the user's opinion, had a higher spectral quality, or whether the spectral qualities of the two products were substantially the same.

A total of 100 well-defined points throughout Milwaukee County were to provide the basis for conducting the spatial accuracy test, of which up to 20 were to be located on elevated bridges. Both the conventional and alternative products were produced within an image boundary file system consisting of "tiles" having 10,000 feet on each side. As shown on Map 1, there are 90 such image files covering Milwaukee County and its immediate environs. A total of 20 tiles were initially randomly selected for the purpose of identifying five test points within each of those tiles. To assure that there was sufficient area within each tile to select points lying in Milwaukee County, any tile that did not have at least 75 percent of its area within the land area of Milwaukee County was eliminated from consideration. This left 63 tile areas from which the sample could be drawn. Each of the 63 tiles was assigned a number, one through 63. Using a random number sequencing process, the sample of 20 tiles was selected. Upon reviewing the sample, it was found that it did not include a tile with a significant number of relatively high level bridges. Accordingly, it was determined to substitute the tile encompassing the Milwaukee harbor area for a tile in the most rural portion of the City of Franklin. All such tiles are identified on Map 1.

Under the direction of the Milwaukee County Surveyor, Commission survey staff identified five well-defined "picture points" within each of the 20 tiles selected for use in the comparative evaluation. These points consisted largely of right-angle sidewalk intersections, right-angle sidewalk-driveway intersections, right-angle intersections of curbs and walks in street medians, and—in a relatively few cases—concrete expansion joint termination locations on bridges. Of the 100 well-defined points ultimately selected for the evaluation, nine were located on elevated bridges. The distribution of these 100 points throughout Milwaukee County is shown on Map 2. Set forth in Appendix C are brief descriptions of the locations of each of the 100 points.

The State Plane Coordinate positions of the 100 test points were then determined under the direction of the Milwaukee County Surveyor using Global Positioning System (GPS) survey techniques and the Wisconsin Department of Transportation continuously operating reference stations (CORS) network established within the Region. A typical field instrumentation set up is shown in Figure 1. The State Plane Coordinate values were determined relative to the North American Datum of 1927—the datum used for the orthophotography—by application of the survey procedure described in Appendix G of SEWRPC Technical Report No. 49, *Bidirectional Transformation of Legacy and Current Survey Control Data Within Southeastern Wisconsin,* May 2010 (copy attached as Appendix D). Utilizing this procedure, the accuracy of the surveys met, or exceeded, Third Order Class II standards.

SUMMARY OF RESULTS

The results of the comparison of field measured point values to orthophotograph-derived point values for both orthophotography products produced for Milwaukee County in 2010 are set forth on Table 1. The shaded entries in this table denote the nine bridge locations included in the sample of 100 "picture points" selected for the comparative analysis.

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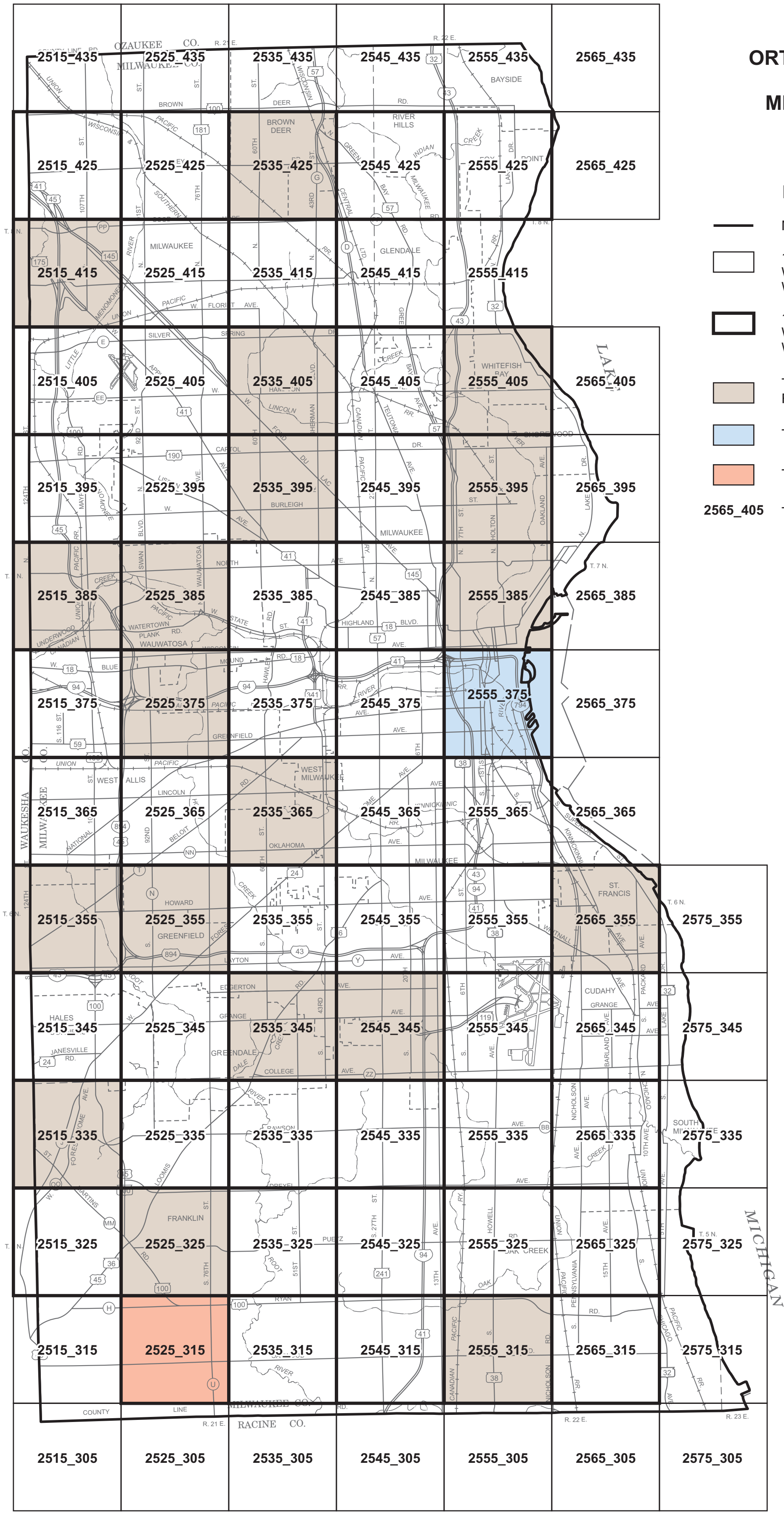
[2]*Other widely recognized horizontal positional accuracy standards include:* American Society of Photogrammetry and Remote Sensing, "Accuracy Standards for Large-Scale Maps", 1989; and Federal Geographic Data Committee, "National Standards for Spatial Data Accuracy," 1998. *A comparison of the National Standards for Spatial Data Accuracy and the National Map Accuracy Standards is provided in Appendix B.*

Map 1

ORTHOPHOTOGRAPHY IMAGE BOUNDARIES IN MILWAUKEE COUNTY: 2010



LEGEND

MILWAUKEE COUNTY

10,000 X 10,000 FEET IMAGE BOUNDARY OR TILE WITH LESS THAN 75 PERCENT OF ITS LAND AREA WITHIN MILWAUKEE COUNTY (26 TILES)

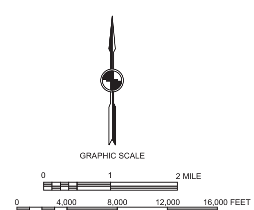
10,000 X 10,000 FEET IMAGE BOUNDARY OR TILE WITH AT LEAST 75 PERCENT OF ITS LAND AREA WITHIN MILWAUKEE COUNTY (63 TILES)

TILE RANDOMLY SELECTED FOR EVALUATION (20 TILES)

TILE ADDED TO SAMPLE (1 TILE)

TILE DELETED FROM SAMPLE (1 TILE)

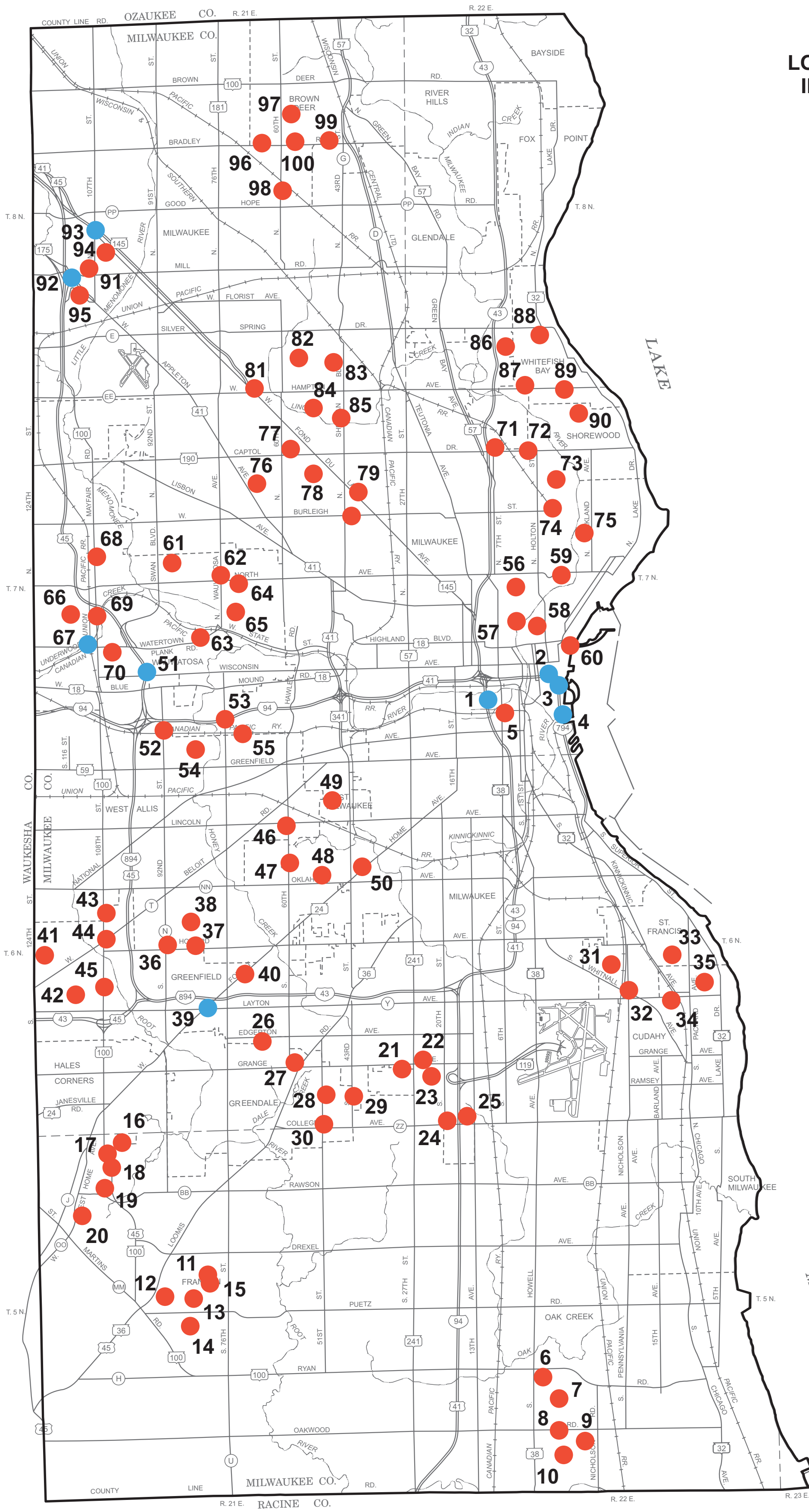
2565_405 TILE IDENTIFICATION NUMBER



Source: SEWRPC.

Map 2

LOCATION OF "PICTURE POINTS" IN 2010 ORTHOPHOTOGRAPHY EVALUATION PROJECT IN MILWAUKEE COUNTY: 2010



LEGEND

FIELD-MEASURED POINT LOCATED AT GROUND LEVEL (91)

FIELD-MEASURED POINT LOCATED ON ELEVATED BRIDGE (9)

48 POINT NUMBER

NOTE: SEE APPENDIX C FOR DETAILED INFORMATION ON EACH POINT

GRAPHIC SCALE

0 1 2 MILE

0 4,000 8,000 12,000 16,000 FEET

Source: SEWRPC.

The following findings may be drawn from the data in Table 1:

1. With respect to the 91 ground-level "picture points" selected for the comparative analysis, National Map Accuracy Standards (NMAS) were met for all such points with respect to both the conventional product produced by AeroMetric Inc. and the AccuPlus product produced by Pictometry International Corp. The average location deviation for the conventional product was 0.72 feet and for the AccuPlus product 0.63 feet.
2. With respect to the nine bridge "picture points" selected for the comparative analysis, all nine such points met NMAS for the conventional product produced by AeroMetric, Inc., with six of the nine such points meeting NMAS for the AccuPlus product produced by Pictometry International Corp. The average location deviation for the conventional product was 0.87 feet and for the AccuPlus product 5.34 feet.
3. With respect to the total of 100 "picture points" selected for the comparative analysis, all such points for the conventional product produced by AeroMetric Inc. met NMAS, while 97 of such points for the AccuPlus product produced by Pictometry International Corp. met NMAS. The average location deviation for the conventional product was 0.73 feet and for the AccuPlus product 1.03 feet.

The foregoing findings lead to the conclusion that both the conventional product produced by AeroMetric, Inc. and the AccuPlus product produced by Pictometry International Corp. in 2010 for Milwaukee County met NMAS, since in both cases at least 90 percent of the positions of well-defined points as determined from the orthophotographs were found to lie within 3.3 feet of their correct position as determined by field measurements.

Figure 1

TYPICAL GPS FIELD INSTRUMENT SETUP USED TO DETERMINE LOCATION OF "PICTURE POINTS" IN MILWAUKEE COUNTY: 2010

Point number 64, at intersection of N. 72nd Street and W. Garfield Avenue, City of Wauwatosa

Source: SEWRPC.

It should be noted that the issue of the accurate location of bridges on the orthophotography should be specifically addressed in any future contracts negotiated for the provision of orthophotography within the seven-county Southeastern Wisconsin Region. Contracts may be negotiated which, for a savings in cost, remain silent on the locational accuracy of relatively high-level bridges. Alternatively, such contracts may be negotiated to include application of the standards to such bridges at, however, some increase in cost. Both AeroMetric, Inc. and Pictometry International Corp. can meet either user preference.

TECHNICAL INFORMATION RELATIVE TO THE ORTHOPHOTOGRAPHY PRODUCTION PROCESSES

To help illuminate the extent to which the orthophotography production processes used by the two contractors may differ, the two contractors—AeroMetric, Inc. and Pictometry International Corp.—were asked to provide comparative information about those processes. That information is set forth in Table 2.

Table 1

RESULTS OF COMPARISONS OF FIELD-MEASURED POINT VALUES TO ORTHOPHOTOGRAPH-DERIVED POINT VALUES: CONVENTIONAL (AERO-METRIC, INC.) AND ACCUPLUS (PICTOMETRY INTERNATIONAL CORP.) ORTHOPHOTOGRAPHY PRODUCTS FOR MILWAUKEE COUNTY: 2010

			Conventional Orthophotography						AccuPlus Orthophotography					
	Field-Measured Values (A)		Conventional Ortho-Derived Values (B)		Difference Between (A) and (B)				AccuPlus Ortho-Derived Values (C)		Difference Between (A) and (C)			
Point Number[a]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	Meets NMAS Standards? (Yes or No)[d]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	Meets NMAS Standards? (Yes or No)[d]
1	2,555,345.67	382,279.71	2,555,345.28	382278.28	-0.39	-1.43	1.48	Yes	2,555,336.16	382,302.49	-9.51	22.79	24.69	No
2	2,560,628.29	384,460.48	2,560,628.42	384,460.35	0.13	-0.13	0.18	Yes	2,560,627.64	384,461.39	-0.65	0.91	1.12	Yes
3	2,561,480.34	383,540.14	2,561,479.95	383,542.10	-0.39	1.95	1.99	Yes	2,561,484.37	383,528.30	4.04	-11.85	12.52	No
4	2,561,821.48	380,958.73	2,561,822.39	380,959.38	0.91	0.65	1.12	Yes	2,561,824.74	380,961.99	3.26	3.26	4.60	No
5	2,556,838.51	381,128.92	2,556,838.64	381,129.83	0.13	0.91	0.92	Yes	2,556,838.38	381,129.83	-0.13	0.91	0.92	Yes
6	2,560,245.66	323,999.94	2,560,245.27	324,000.07	-0.39	0.13	0.41	Yes	2,560,245.79	324,000.07	0.13	0.13	0.18	Yes
7	2,561,512.71	322,178.22	2,561,512.84	322,178.61	0.13	0.39	0.41	Yes	2,561,512.84	322,178.35	0.13	0.13	0.18	Yes
8	2,561,492.61	319,402.61	2,561,492.74	319,402.74	0.13	0.13	0.18	Yes	2,561,492.74	319,402.48	0.13	-0.13	0.18	Yes
9	2,563,747.39	318,468.85	2,563,748.05	318,468.98	0.65	0.13	0.66	Yes	2,563,747.78	318,469.24	0.39	0.39	0.55	Yes
10	2,561,863.74	317,282.68	2,561,863.61	317,283.07	-0.13	0.39	0.41	Yes	2,561,863.87	317,282.81	0.13	0.13	0.18	Yes
11	2,531,125.89	332,628.98	2,531,126.54	332,629.37	0.65	0.39	0.76	Yes	2,531,126.28	332,629.37	0.39	0.39	0.55	Yes
12	2,527,684.17	330,861.12	2,527,684.82	330,861.25	0.65	0.13	0.66	Yes	2,527,684.30	330,861.51	0.13	0.39	0.41	Yes
13	2,529,907.39	330,790.27	2,529,908.56	330,790.40	1.17	0.13	1.18	Yes	2,529,907.78	330,790.14	0.39	-0.13	0.41	Yes
14	2,529,625.06	328,389.62	2,529,625.45	328,389.75	0.39	0.13	0.41	Yes	2,529,625.45	328,390.27	0.39	0.65	0.76	Yes
15	2,531,246.58	332,114.73	2,531,246.97	332,115.38	0.39	0.65	0.76	Yes	2,531,246.97	332,115.12	0.39	0.39	0.55	Yes
16	2,523,809.20	344,061.95	2,523,808.03	344,062.86	-1.17	0.91	1.48	Yes	2,523,807.51	344,062.60	-1.69	0.65	1.81	Yes
17	2,522,520.76	343,185.75	2,522,521.67	343,185.36	0.91	-0.39	0.99	Yes	2,522,520.89	343,185.62	0.13	-0.13	0.18	Yes
18	2,522,858.51	341,971.73	2,522,859.16	341,972.38	0.65	0.65	0.92	Yes	2,522,858.38	341,972.12	-0.13	0.39	0.41	Yes
19	2,522,333.21	340,220.19	2,522,334.12	340,220.58	0.91	0.39	0.99	Yes	2,522,333.34	340,220.06	0.13	-0.13	0.18	Yes
20	2,520,268.17	337,874.65	2,520,268.82	337,875.56	0.65	0.91	1.12	Yes	2,520,268.82	337,874.52	0.65	-0.13	0.66	Yes
21	2,547,889.32	350,479.51	2,547,889.71	350,480.42	0.39	0.91	0.99	Yes	2,547,889.45	350,480.42	0.13	0.91	0.92	Yes
22	2,549,846.61	351,182.76	2,549,847.26	351,183.41	0.65	0.65	0.92	Yes	2,549,847.00	351,183.93	0.39	1.17	1.24	Yes
23	2,550,435.83	349,849.42	2,550,435.70	349,850.59	-0.13	1.17	1.18	Yes	2,550,436.48	349,850.33	0.65	0.91	1.12	Yes
24	2,551,859.74	345,950.26	2,551,859.87	345,951.18	0.13	0.91	0.92	Yes	2,551,859.87	345,951.44	0.13	1.17	1.18	Yes
25	2,553,554.70	346,310.16	2,553,555.09	346,309.77	0.39	-0.39	0.55	Yes	2,553,554.83	346,310.81	0.13	0.65	0.66	Yes
26	2,535,862.19	352,877.30	2,535,862.32	352,878.47	0.13	1.17	1.18	Yes	2,535,862.06	352,877.95	-0.13	0.65	0.66	Yes

Table 1 (continued)

Point Number[a]	Field-Measured Values (A)		Conventional Orthophotography						AccuPlus Orthophotography					
			Conventional Ortho-Derived Values (B)		Difference Between (A) and (B)			Meets NMAS Standards? (Yes or No)[d]	AccuPlus Ortho-Derived Values (C)		Difference Between (A) and (C)			Meets NMAS Standards? (Yes or No)[d]
	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]		Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	
27	2,538,646.76	350,933.30	2,538,647.15	350,933.69	0.39	0.39	0.55	Yes	2,538,646.10	350,933.96	-0.65	0.65	0.92	Yes
28	2,541,402.20	348,248.63	2,541,402.33	348,249.02	0.13	0.39	0.41	Yes	2,541,402.33	348,249.28	0.13	0.65	0.66	Yes
29	2,543,792.03	348,064.27	2,543,791.90	348,064.92	-0.13	0.65	0.66	Yes	2,543,791.64	348,065.44	-0.39	1.17	1.24	Yes
30	2,541,242.07	345,695.84	2,541,242.72	345,697.01	0.65	1.17	1.34	Yes	2,541,242.46	345,696.75	0.39	0.91	0.99	Yes
31	2,566,040.11	359,431.83	2,566,039.72	359,432.74	-0.39	0.91	0.99	Yes	2,566,040.24	359,432.22	0.13	0.39	0.41	Yes
32	2,567,582.01	357,213.32	2,567,581.62	357,214.23	-0.39	0.91	0.99	Yes	2,567,581.62	357,213.71	-0.39	0.39	0.55	Yes
33	2,571,389.42	360,328.79	2,571,389.03	360,329.96	-0.39	1.17	1.24	Yes	2,571,389.03	360,328.92	-0.39	0.13	0.41	Yes
34	2,571,319.95	356,368.53	2,571,319.56	356,369.71	-0.39	1.17	1.24	Yes	2,571,319.56	356,369.19	-0.39	0.65	0.76	Yes
35	2,574,075.96	357,923.19	2,574,075.31	357,924.36	-0.65	1.17	1.34	Yes	2,574,075.31	357,923.84	-0.65	0.65	0.92	Yes
36	2,527,701.03	361,160.35	2,527,701.16	361,160.74	0.13	0.39	0.41	Yes	2,527,700.64	361,160.74	-0.39	0.39	0.55	Yes
37	2,530,155.98	361,136.76	2,530,156.63	361,137.42	0.65	0.65	0.92	Yes	2,530,155.59	361,137.15	-0.39	0.39	0.55	Yes
38	2,529,747.00	363,132.32	2,529,747.13	363,132.45	0.13	0.13	0.18	Yes	2,529,746.61	363,132.45	-0.39	0.13	0.41	Yes
39	2,531,301.68	355,940.17	2,531,302.07	355,940.82	0.39	0.65	0.76	Yes	2,531,302.59	355,940.82	0.91	0.65	1.12	Yes
40	2,534,414.62	358,621.59	2,534,414.75	358,621.98	0.13	0.39	0.41	Yes	2,534,414.23	358,621.98	-0.39	0.39	0.55	Yes
41	2,517,136.55	360,221.24	2,517,136.68	360,221.63	0.13	0.39	0.41	Yes	2,517,136.68	360,220.85	0.13	-0.39	0.41	Yes
42	2,519,851.35	356,879.40	2,519,852.26	356,879.79	0.91	0.39	0.99	Yes	2,519,851.22	356,880.05	-0.13	0.65	0.66	Yes
43	2,522,441.08	363,897.17	2,522,441.73	363,898.08	0.65	0.91	1.12	Yes	2,522,440.95	363,897.30	-0.13	0.13	0.18	Yes
44	2,522,603.88	361,737.19	2,522,604.79	361,738.36	0.91	1.17	1.48	Yes	2,522,604.01	361,737.84	0.13	0.65	0.66	Yes
45	2,522,469.94	357,472.41	2,522,471.11	357,473.84	1.17	1.43	1.85	Yes	2,522,469.80	357,473.06	-0.13	0.65	0.66	Yes
46	2,537,947.93	371,378.62	2,537,948.06	371,379.53	0.13	0.91	0.92	Yes	2,537,948.06	371,379.53	0.13	0.91	0.92	Yes
47	2,538,312.17	368,082.36	2,538,312.56	368,083.27	0.39	0.91	0.99	Yes	2,538,312.30	368,082.49	0.13	0.13	0.18	Yes
48	2,540,987.71	367,170.69	2,540,987.84	367,171.08	0.13	0.39	0.41	Yes	2,540,987.58	367,170.82	-0.13	0.13	0.18	Yes
49	2,541,897.05	373,525.96	2,541,896.92	373,526.61	-0.13	0.65	0.66	Yes	2,541,897.44	373,526.87	0.39	0.91	0.99	Yes
50	2,544,488.26	367,886.54	2,544,487.87	367,886.93	-0.39	0.39	0.55	Yes	2,544,488.13	367,887.19	-0.13	0.65	0.66	Yes
51	2,526,008.73	384,645.33	2,526,008.59	384,645.20	-0.13	-0.13	0.18	Yes	2,526,008.33	384,643.12	-0.39	-2.21	2.25	Yes
52	2,527,532.22	380,050.27	2,527,532.61	380,051.18	0.39	0.91	0.99	Yes	2,527,532.09	380,050.66	-0.13	0.39	0.41	Yes
53	2,532,636.62	380,824.71	2,532,636.75	380,825.62	0.13	0.91	0.92	Yes	2,532,637.27	380,825.36	0.65	0.65	0.92	Yes
54	2,530,191.19	378,021.28	2,530,192.36	378,021.67	1.17	0.39	1.24	Yes	2,530,191.58	378,021.67	0.39	0.39	0.55	Yes
55	2,534,205.35	379,291.19	2,534,205.22	379,292.36	-0.13	1.17	1.18	Yes	2,534,204.70	379,292.36	-0.65	1.17	1.34	Yes

Table 1 (continued)

Point Number[a]	Field-Measured Values (A)		Conventional Orthophotography						AccuPlus Orthophotography					
			Conventional Ortho-Derived Values (B)		Difference Between (A) and (B)				AccuPlus Ortho-Derived Values (C)		Difference Between (A) and (C)			
	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	Meets NMAS Standards? (Yes or No)[d]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	Meets NMAS Standards? (Yes or No)[d]
56	2,557,800.48	392,060.11	2,557,800.35	392,059.98	-0.13	-0.13	0.18	Yes	2,557,800.09	392,060.76	-0.39	0.65	0.76	Yes
57	2,557,851.15	389,056.07	2,557,850.76	389,056.72	-0.39	0.65	0.76	Yes	2,557,850.76	389,056.72	-0.39	0.65	0.76	Yes
58	2,559,676.57	388,639.54	2,559,676.43	388,640.45	-0.13	0.91	0.92	Yes	2,559,676.43	388,639.93	-0.13	0.39	0.41	Yes
59	2,561,716.30	393,054.26	2,561,715.91	393,054.91	-0.39	0.65	0.76	Yes	2,561,716.43	393,054.39	0.13	0.13	0.18	Yes
60	2,562,496.50	386,929.93	2,562,496.36	386,930.85	-0.13	0.91	0.92	Yes	2,562,496.36	386,930.32	-0.13	0.39	0.41	Yes
61	2,528,078.29	394,067.41	2,528,078.42	394,067.54	0.13	0.13	0.18	Yes	2,528,078.68	394,067.80	0.39	0.39	0.55	Yes
62	2,532,291.29	393,012.18	2,532,291.68	393,013.35	0.39	1.17	1.24	Yes	2,532,291.16	393,013.09	-0.13	0.91	0.92	Yes
63	2,530,524.91	387,644.21	2,530,525.04	387,645.12	0.13	0.91	0.92	Yes	2,530,524.26	387,645.12	-0.65	0.91	1.12	Yes
64	2,533,909.14	392,298.48	2,533,909.01	392,298.87	-0.13	0.39	0.41	Yes	2,533,909.27	392,299.13	0.13	0.65	0.66	Yes
65	2,533,597.15	389,879.11	2,533,597.28	389,879.50	0.13	0.39	0.41	Yes	2,533,597.02	389,879.76	-0.13	0.65	0.66	Yes
66	2,519,387.77	389,781.04	2,519,387.64	389,781.43	-0.13	0.39	0.41	Yes	2,519,387.90	389,781.17	0.13	0.13	0.18	Yes
67	2,520,854.78	387,118.94	2,520,854.65	387,119.33	-0.13	0.39	0.41	Yes	2,520,854.65	387,118.29	-0.13	-0.65	0.66	Yes
68	2,521,749.56	394,639.97	2,521,749.43	394,639.84	-0.13	-0.13	0.18	Yes	2,521,749.43	394,639.84	-0.13	-0.13	0.18	Yes
69	2,521,691.14	390,236.56	2,521,691.27	390,236.95	0.13	0.39	0.41	Yes	2,521,691.01	390,236.95	-0.13	0.39	0.41	Yes
70	2,522,969.67	386,351.09	2,522,969.80	386,352.00	0.13	0.91	0.92	Yes	2,522,969.02	386,352.00	-0.65	0.91	1.12	Yes
71	2,555,994.19	404,025.59	2,555,993.80	404,025.72	-0.39	0.13	0.41	Yes	2,555,994.32	404,025.98	0.13	0.39	0.41	Yes
72	2,558,825.89	403,771.73	2,558,825.50	403,772.12	-0.39	0.39	0.55	Yes	2,558,825.76	403,772.39	-0.13	0.65	0.66	Yes
73	2,561,291.85	401,258.10	2,561,290.94	401,258.75	-0.91	0.65	1.12	Yes	2,561,291.46	401,258.75	-0.39	0.65	0.76	Yes
74	2,561,016.60	398,790.33	2,561,016.47	398,790.98	-0.13	0.65	0.66	Yes	2,561,016.73	398,790.98	0.13	0.65	0.66	Yes
75	2,563,785.11	396,690.37	2,563,784.72	396,690.50	-0.39	0.13	0.41	Yes	2,563,785.24	396,690.50	0.13	0.13	0.18	Yes
76	2,535,817.39	401,073.85	2,535,817.52	401,074.50	0.13	0.65	0.66	Yes	2,535,817.26	401,074.50	-0.13	0.65	0.66	Yes
77	2,538,277.18	403,990.53	2,538,277.31	403,990.40	0.13	-0.13	0.18	Yes	2,538,277.31	403,990.66	0.13	0.13	0.18	Yes
78	2,540,327.68	401,797.32	2,540,327.29	401,797.71	-0.39	0.39	0.55	Yes	2,540,327.55	401,797.71	-0.13	0.39	0.41	Yes
79	2,544,113.79	400,259.70	2,544,114.70	400,260.09	0.91	0.39	0.99	Yes	2,544,114.70	400,260.35	0.91	0.65	1.12	Yes
80	2,543,565.33	398,135.94	2,543,566.24	398,135.80	0.91	-0.13	0.92	Yes	2,543,565.98	398,136.33	0.65	0.39	0.76	Yes
81	2,535,239.78	409,165.61	2,535,239.39	409,165.74	-0.39	0.13	0.41	Yes	2,535,240.17	409,166.00	0.39	0.39	0.55	Yes
82	2,539,005.44	411,853.37	2,539,005.31	411,853.24	-0.13	-0.13	0.18	Yes	2,539,005.05	411,853.24	-0.39	-0.13	0.41	Yes
83	2,542,028.33	411,450.65	2,542,028.20	411,451.04	-0.13	0.39	0.41	Yes	2,542,028.20	411,451.04	-0.13	0.39	0.41	Yes
84	2,540,285.23	407,462.26	2,540,285.10	407,462.92	-0.13	0.65	0.66	Yes	2,540,285.36	407,463.18	0.13	0.91	0.92	Yes

Table 1 (continued)

Point Number[a]	Field-Measured Values (A)		Conventional Orthophotography						AccuPlus Orthophotography					
			Conventional Ortho-Derived Values (B)		Difference Between (A) and (B)			Meets NMAS Standards? (Yes or No)[d]	AccuPlus Ortho-Derived Values (C)		Difference Between (A) and (C)			Meets NMAS Standards? (Yes or No)[d]
	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]		Easting[b]	Northing[b]	Easting[b]	Northing[b]	Deviation from Field Position[c]	
85	2,542,661.98	406,597.29	2,542,662.11	406,597.42	0.13	0.13	0.18	Yes	2,542,662.11	406,597.42	0.13	0.13	0.18	Yes
86	2,556,916.90	412,778.40	2,556,916.77	412,778.01	-0.13	-0.39	0.41	Yes	2,556,917.29	412,777.75	0.39	-0.65	0.76	Yes
87	2,558,574.45	409,410.42	2,558,573.80	409,410.55	-0.65	0.13	0.66	Yes	2,558,574.58	409,410.55	0.13	0.13	0.18	Yes
88	2,559,826.03	413,786.87	2,559,825.90	413,785.96	-0.13	-0.91	0.92	Yes	2,559,826.94	413,786.48	0.91	-0.39	0.99	Yes
89	2,561,982.57	409,098.37	2,561,982.70	409,099.02	0.13	0.65	0.66	Yes	2,561,982.96	409,098.50	0.39	0.13	0.41	Yes
90	2,563,280.71	406,992.63	2,563,280.84	406,992.50	0.13	-0.13	0.18	Yes	2,563,280.84	406,993.02	0.13	0.39	0.41	Yes
91	2,520,975.43	419,602.43	2,520,975.82	419,603.08	0.39	0.65	0.76	Yes	2,520,975.29	419,603.08	-0.13	0.65	0.66	Yes
92	2,519,487.30	418,651.34	2,519,487.95	418,651.99	0.65	0.65	0.92	Yes	2,519,487.43	418,651.99	0.13	0.65	0.66	Yes
93	2,521,723.31	423,349.84	2,521,723.96	423,350.23	0.65	0.39	0.76	Yes	2,521,723.44	423,350.23	0.13	0.39	0.41	Yes
94	2,522,376.21	420,966.85	2,522,376.60	420,967.50	0.39	0.65	0.76	Yes	2,522,376.08	420,967.24	-0.13	0.39	0.41	Yes
95	2,520,147.79	417,233.74	2,520,147.92	417,233.87	0.13	0.13	0.18	Yes	2,520,147.66	417,234.13	-0.13	0.39	0.41	Yes
96	2,535,818.30	430,327.86	2,535,818.17	430,327.99	-0.13	0.13	0.18	Yes	2,535,818.43	430,327.99	0.13	0.13	0.18	Yes
97	2,538,322.61	432,837.46	2,538,322.48	432,837.33	-0.13	-0.13	0.18	Yes	2,538,322.22	432,838.11	-0.39	0.65	0.76	Yes
98	2,537,638.53	426,273.15	2,537,638.39	426,272.76	-0.13	-0.39	0.41	Yes	2,537,638.39	426,273.54	-0.13	0.39	0.41	Yes
99	2,541,593.64	430,557.39	2,541,593.51	430,557.00	-0.13	-0.39	0.41	Yes	2,541,593.51	430,557.78	-0.13	0.39	0.41	Yes
100	2,538,652.24	430,476.98	2,538,652.37	430,476.84	0.13	-0.13	0.18	Yes	2,538,652.37	430,477.37	0.13	0.39	0.41	Yes

[a] *See Map 2. Shading on the table denotes elevated bridge location.*

[b] *Point locations are measured on the Wisconsin State Plane Coordinate System, South Zone, North American Datum of 1927. All units expressed in Survey feet.*

[c] *The formula to calculate this distance is:*
Distance = Square Root of [(difference in Easting)^2 + (difference in Northing)^2]

[d] *U.S. National Map Accuracy Standards (NMAS) are specified according to the scale of the published map. For maps at a publication scale of one inch equals 100 feet (1:1200), the NMAS states that at least 90 percent of the points tested shall be within 3.3 feet of their true position on the ground. According to this comparison of field-measured and ortho-measured points, all 100 points located on the conventional orthophotography are within 3.3 feet of their true position, and 97 of the 100 points located on the AccuPlus orthophotography are within 3.3 feet of their true position. Therefore, both the conventional orthophotography and the AccuPlus orthophotography products meet National Map Accuracy Standards.*

Source: SEWRPC.

Table 2

COMPARISON OF TECHNIQUES AND PROCESSES USED BY THE FIRMS THAT PRODUCED ORTHOPHOTOGRAPHY FOR MILWAUKEE COUNTY: 2010

Category	Item	Conventional Orthophotography AeroMetric, Inc.	AccuPlus Orthophotography Pictometry International Corp.
Flight	Flight date range	March 30-31, 2010	April 10-13, 2010
	Type of camera	Digital Mapping Camera (DMC), Zeiss Intergraph	Pictometry Penta View
	Focal length	4.724 inches	65mm (3.438 inches)
	Pixel size	12 microns	7.4 microns
	Pixel array	13,700 x 7,500 pixels	4,872 x 3,248 pixels
	Flight altitude above average terrain	5,000 feet (nominal)	3,500 feet (nominal)
	Number of flight lines	120	147
	Sidelap(s) used	27% (nominal,) 80% in downtown area	35% (nominal)
	Forward lap(s) used	60% (nominal,) 80% in downtown area	66% (nominal)
	Number of frames for entire project (nadir view)	1,632	Approximate 25,000 frames collected
	Were all exposures used to process the orthophoto imagery?	All except excess frames at ends of lines. Also, coverage was duplicated in some areas to reduce building lean	Not all captured frames were used for the mosaic
	Area covered by each image	6,800 feet x 3,750 feet (nominal)	2,400 feet x 1,600 feet (nominal)
	Ground sample distance of input images	0.5 feet (nominal)	4.78 inch (nominal)
Georeferencing	Number of control points used	40	78
	Was Airborne Global Positioning utilized?	Yes	Yes
	Were Inertial Measuring Unit Technologies utilized?	Yes	Yes
	Method used to register images to survey control network	Match AT from Inpho software	Match AT from Inpho software
	Root Mean Square Error (RMSE) of survey control points used to register images	RMSE (x) = 0.24 feet; RMSE (y) = 0.20 feet	RMSE(x) = 0.13 feet; RMSE (y) = 0.19 feet
Image Processing[a]	Bits of resolution per band	12-bit per channel - resampled to 8-bit during initial processing	12-bit per channel - resampled to 8-bit during initial processing
	Was Pan-sharpening employed?	Yes	No
	Radiometric adjustment used	Tone balancing of brightness and contrast followed by histogram feathering of spectral values for nearby pixels on adjacent images	Pictometry utilizes a custom designed proprietary radiometric adjustment technique
Digital Elevation Model	Source of elevation data	Existing DEM from stereo photographs	Pictometry LiDAR derived DEM
	What Sensor(s) were used to collect elevation data (LiDAR or Photogrammetry)?	Aerial film and DMC cameras	Optech ALTM Gemini
	Were break lines added to improve elevations?	Yes, along elevated transportation features	Not part of specifications at time of contracting
Orthorectification	Sampling technique used	Cubic convolution	Cubic convolution
	Was image compression used?	No	No
	Seamline generation technique used	Manual seamlines	Automatic with manual edit
	Software used	Orthopro and OrthoVista	Ortho-Vista
Tile Production	Was mosaicking employed?	Yes	Yes
Accuracy Assessment	Number of internal quality assurance points used	40-Plus	Various control points were used as check throughout the AT process. All available control was used for the final adjustment.
	Allowable pixel mismatch along seamlines	0-3	1
	Absolute accuracy	NMAS for 1:1200 feet mapping scale	To be determined by Technical Advisory Committee
	Accuracy standard used	NMAS standard where 90 percent of the well defined points are within 3.3 feet of their true position	To be determined by Technical Advisory Committee

[a]*The following definitions apply to terms used in this section of the table:*
Pan Sharpening: A process of transforming a set of lower (coarse) resolution color images to higher (finer) spatial resolution color images, by fusing the color images with a co-registered fine spatial resolution panchromatic (black/white) image.
Tone balancing: Adjustments made to the brightness of an image and the contrast within the image.
Histogram: A plot of the number of pixels in the image (vertical axis) with a particular brightness value (horizontal axis).
Histogram matching: A method in image processing of color adjustment. In some instances a reference histogram for the project is determined and then individual image histograms are shifted (normalized) to better match the reference histogram. In other cases, the spectral differences caused by different histograms are feathered to match the adjacent image.

Source: AeroMetric, Inc., Pictometry International Corp., and SEWRPC.

Table 3

MILWAUKEE COUNTY ORTHOPHOTOGRAPH PRODUCT COSTS: 2010

Firm	Total Cost	Cost per square mile	Deliverables
Aero-Metric, Inc.	$173,310	$716	• Six-inch pixel resolution orthophotography in GeoTIFF file format • Orthophoto elevation model suitable for ortho rectification
Pictometry International, Inc.	$118,944[a]	$492	• Six-inch pixel resolution orthophotography in GeoTIFF file format • Oblique images in proprietary format for entire county • Pictometry software and license (Electronic Field Study software for use in viewing and measuring ortho and oblique imagery) • Software training and telephone support • Triangulated nadir frames/camera models • LiDAR data captured and available at additional cost

[a]*The total cost for the Pictometry product includes a discount of $13,216 as a 10 percent long term incentive for executing a six-year agreement. Under this agreement Milwaukee County is committed to acquiring updated products every two years provided that funds are available. Excluding this discount, the total cost is $132,160 or approximately $546 per square mile.*

Source: AeroMetric, Inc., Pictometry International Corp., and SEWRPC.

COMPARATIVE ORTHOPHOTOGRAPHY COSTS

The costs of producing the two sets of orthophotography products for Milwaukee County in 2010 are summarized in Table 3. The cost of the Pictometry International Corp. product approximated $492 per square mile. The cost of the AeroMetric, Inc. product approximated $716 per square mile. Table 3 also lists the array of materials delivered under the contracts concerned. The deliverables from Pictometry International Corp. include, in addition to the orthophotographs, oblique images and proprietary software and a license for software use in viewing and measuring the oblique imagery.

SPECTRAL QUALITY EVALUATION WEBSITE LINK

As part of the project, MCAMLIS staff developed a website presence to enable individuals to comparatively evaluate the spectral quality of the two orthophography products delivered in 2010. Through use of the application provided in the MCAMLIS website, the viewer is able to examine the two sets of orthophotography products side-by-side in any area of Milwaukee County. This site may be accessed at the following link: http://www.county.milwaukee.gov/ImageLibrary/User/bshaw/Ortho_Comparative_Study_2010.pdf

APPENDICES

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Appendix A

THE 2010 SEWRPC REGIONAL ORTHOPHOTOGRAPHY PROJECT

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Appendix A-1

ORTHOPHOTOGRAPHY PROJECT REVENUES AND EXPENDITURES: 2010

Revenues		
U.S. Department of Transportation (STP-M)		$ 600,000
U.S. Geological Survey		156,000
• County Apportionment for Base Product:		
Kenosha	$ 6,221	
Milwaukee	5,436	
Ozaukee	5,255	
Racine	7,671	
Walworth	12,986	
Washington	9,785	
Waukesha	13,046	
Total County Contribution to Base Product		60,400
• County/Local "Buy Up" to Upgraded Products:		
Kenosha *(3-inch with LiDAR)*	211,726	
Milwaukee *(6-inch)*	27,799	
Washington *(6-inch)*	49,209	
Waukesha *(6-inch)*	109,594	
City of Mequon *(6-inch with LiDAR)*	9,460	
City of Racine *(6-inch duplicate orthophotos)*	17,385	
Total Buy Up Contribution		425,173
New Product Evaluation		23,789
(Milwaukee County match funds for AccuPlus by Pictometry)		
Total Revenues	- -	$1,265,362
Expenditures		
Expenditures by Product Type:		
• Three Counties – 12-inch Base Product		
Ozaukee *(excluding Mequon)*	$ 26,373	
Racine	48,426	
Walworth	81,980	
Subtotal	156,779	
• Three Counties / One City – 6-inch Enhanced Product		
Milwaukee	173,310	
Washington	162,980	
Waukesha	233,955	
City of Mequon	16,260	
Subtotal	586,505	
• Kenosha County – 3-inch LiDAR Enhanced Product	271,000	
Aero-Metric – Regional Orthophoto Contract		$1,014,284
Aero-Metric – City of Racine 6-inch duplicate orthos		17,385
Pictometry International Corp. – AccuPlus Imagery		118,944
SEWRPC – Project Management, Quality Control, and Evaluation of Project		144,749
Total Expenditures	- -	$1,265,362

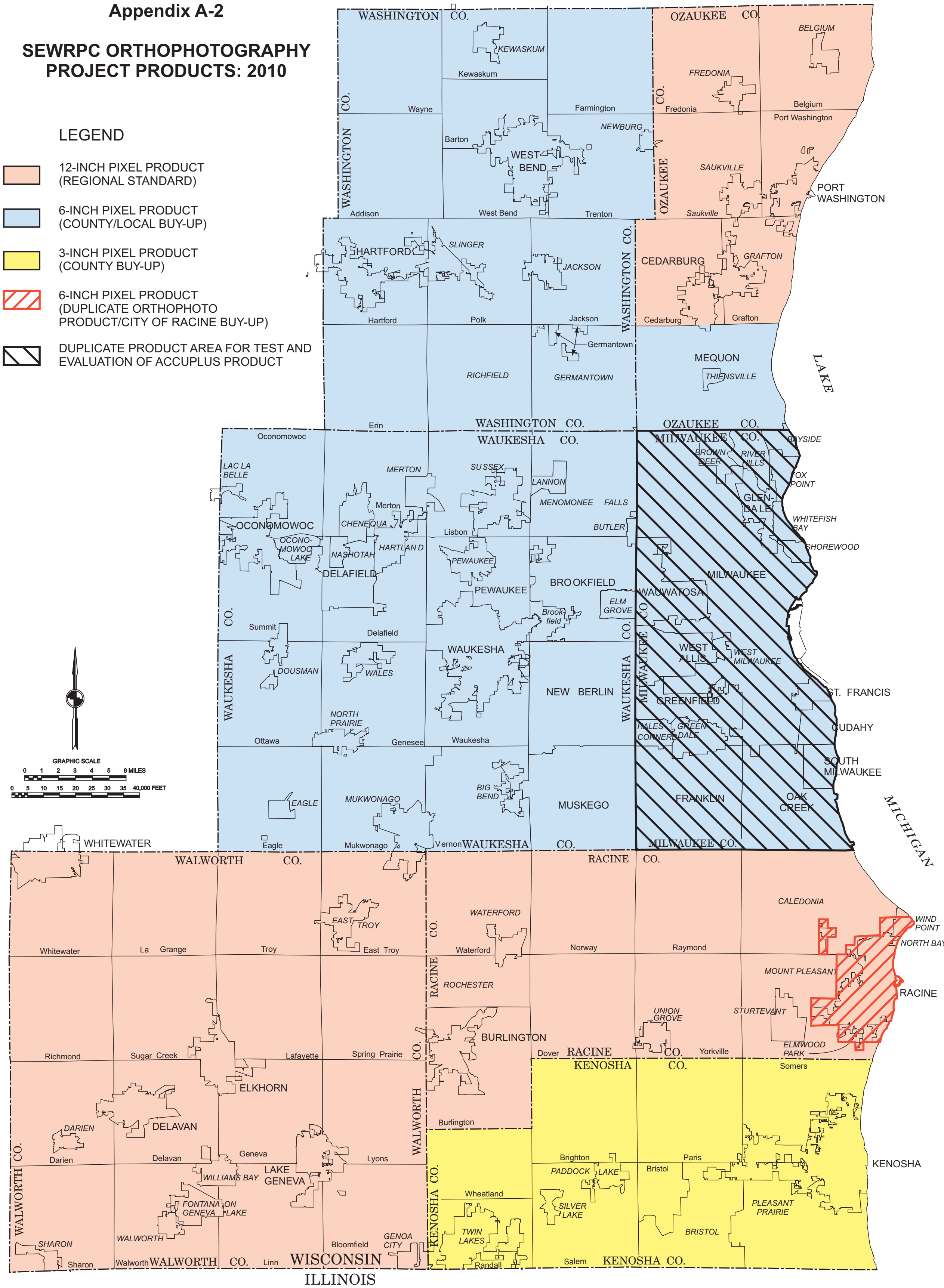
Source: SEWRPC.

Appendix A-2

SEWRPC ORTHOPHOTOGRAPHY PROJECT PRODUCTS: 2010

LEGEND

- 12-INCH PIXEL PRODUCT (REGIONAL STANDARD)
- 6-INCH PIXEL PRODUCT (COUNTY/LOCAL BUY-UP)
- 3-INCH PIXEL PRODUCT (COUNTY BUY-UP)
- 6-INCH PIXEL PRODUCT (DUPLICATE ORTHOPHOTO PRODUCT/CITY OF RACINE BUY-UP)
- DUPLICATE PRODUCT AREA FOR TEST AND EVALUATION OF ACCUPLUS PRODUCT



Source: SEWRPC.

Appendix B

UNITED STATES NATIONAL MAP ACCURACY STANDARDS

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Appendix B

UNITED STATES NATIONAL MAP ACCURACY STANDARDS

1. Horizontal accuracy. For maps with publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30th inch, measured at the publication scale; for maps with publication scales of 1:20,000 or smaller, 1/50th inch. These limits of accuracy shall apply to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads and railroads; corners of large buildings or structures (or center points of small buildings). In general, what is well defined will also be determined by what is plottable on the scale of the map within 1/100th inch. Thus, while the intersection of two roads or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would not be practicable within 1/100th inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. This class would cover timber lines and soil boundaries.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error by more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. Published maps meeting these accuracy requirements shall note this fact in their legends, as follows: "This map complies with National Map Accuracy Standards."

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, 'This map is an enlargement of a 1:20,000-scale map drawing,' or 'This map is an enlargement of a 1:24,000-scale published map.'

7. To facilitate ready interchange and use of basic information for map construction among all Federal map-making agencies, manuscript maps and published maps, wherever economically feasible and consistent with the use to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3.75 minutes in size.

Source: Reproduced from Appendix F, SEWRPC Technical Report No. 7, Horizontal and Vertical Survey Control in Southeastern Wisconsin, 1996.

COMPARISON OF NSSDA AND NMAS

National Standard for Spatial Data Accuracy (NSSDA)
The NSSDA was conceived in 1989 and approved in 1998 by the Federal Geospatial Data Committee (FGDC) for use with digital spatial data. The standard was intended to recognize that the scale of digital maps and aerial photographs could be readily changed by use of the "zoom" feature of computer software programs and hardware equipment. Thus the specified accuracy was intended to be the same no matter at what scale the data were viewed. The NSSDA is expressed as a 95th percentile standard, which means that when test points—at least 20—in the dataset are checked against an independent dataset of higher accuracy covering the same area, 95 percent of those test points must be within the specified accuracy value.

NSSDA accuracy can be reported as either "tested" or "compiled to meet." A "tested" accuracy value report is intended to indicate that the dataset concerned was actually tested against an independent dataset of higher accuracy according to NSSDA guidelines. The "compiled to meet" accuracy value report is intended to indicate that several datasets that were produced using the same methodology were tested and all produced a consistent NSSDA accuracy value, that the dataset concerned was not tested, but was produced using the same procedure as other previously tested datasets. The accuracy value may then be assumed to be at least as good as the least accurate dataset that was tested. And it is the "least accurate" value that is reported. The complete NSSDA standard can be found at: http://www.fgdc.gov/standards/documents/standards/ accuracy/chapter3.pdf.

National Map Accuracy Standards (NMSA)
The NMAS were created in 1941 and revised in 1947. The standard was designed for use with hardcopy maps where the map and features depicted on it were intended for publication and use at a specified scale. The accuracy can be reported as a ratio or scale, an equation, or as a 90th percentile error. Specific standards are provided for both horizontal and for vertical accuracy. The Commission considers the NMAS to be more stringent as well as simpler and more practical than the NSSDA standards.

The following table provides a comparison of the two standards.

NMAS Map Scale	NMAS CMAS 90 percent confidence level Maximum Error Tolerance	NSSDA $Accuracy_r$ 95 percent confidence level	NSSDA $RMSE_r$
1"=100' 1:1,200	3.33 feet	3.80 feet	2.20 feet
1"=200' 1:2,400	6.67 feet	7.60 feet	4.39 feet
1"=400' 1:4,800	13.33 feet	15.21 feet	8.79 feet
1"=500' 1:6,000	16.67 feet	19.01 feet	10.98 feet
1"=1,000' 1:12,000	33.33 feet	38.02 feet	21.97 feet
1"=2,000' 1:24,000[a]	40.00 feet	45.62 feet	26.36 feet

[a]The 1:24,000- and 1:25,000-scales of USGS 7.5-minute quadrangles are smaller than 1:20,000 therefore, the NMAS horizontal accuracy test for well-defined test points is based on 1/50 inch, rather than 1/30 inch for maps with scales larger than 1:20,000.

Source: National Digital Elevation Program, May 2004 and SEWRPC.

Appendix C

DESCRIPTION OF FIELD-MEASURED "PICTURE POINT" LOCATIONS

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Appendix C

DESCRIPTION OF FIELD-MEASURED "PICTURE POINT" LOCATIONS

Point Number	Easting	Northing	Location Description
1	2,555,345.67	382,279.71	Bridge Point: South end of barrier wall between southbound on-ramp and southbound IH 94 / 43 at pavement, on overpass above and south of Canal St., Milwaukee
2	2,560,628.29	384,460.48	Bridge Point: Northerly most point of pavement joint on bridge, eastbound lanes of IH 794 where interstate turns from eastbound to southbound, above E. St. Paul Ave., Milwaukee
3	2,561,480.34	383,540.14	Bridge Point: Easterly most point of pavement joint on bridge of IH 794 exit ramp, overpass of E. Chicago St., overpass on west side of Meier Festival Park, Milwaukee
4	2,561,821.48	380,958.73	Bridge Point: Easterly most point of pavement joint on bridge, north end of Hoan Bridge, Milwaukee
5	2,556,838.51	381,128.92	Easterly intersection of sidewalks, southeast side of roundabout that connects S. 6th St., S. 5th St., and W. Florida Ave., Milwaukee
6	2,560,245.66	323,999.94	Southwest corner of intersection of sidewalks, southwest of intersection of Austin St. and Larson Lane, Oak Creek
7	2,561,512.71	322,178.22	Northeast corner of intersection of sidewalks, southeast of intersection of E. Fitzsimmons Rd. and Darlene Lane, Oak Creek
8	2,561,492.61	319,402.61	Southeast end of grass median island, north edge of south island nose at inside edge of east curb, intersection of Ashley Lane and Hobby Lane, Oak Creek
9	2,563,747.39	318,468.85	Northeast corner of intersection of sidewalks, southeast of Meadowview Elementary School, east side of McGraw Dr., 10420 S. McGraw Dr., Oak Creek
10	2,561,863.74	317,282.68	Northwest corner of intersection of sidewalks, northeast of intersection of Jessica Dr. and Mary Lane, Oak Creek
11	2,531,125.89	332,628.98	Intersection of sidewalk and curb to northeast of walk, south side of Forest Meadows Ct. and west side of Forest Meadows Dr., Franklin
12	2,527,684.17	330,861.12	Northeast corner of intersection of sidewalks, inside corner of right angle bend of sidewalks, intersection of Brenwood Park Dr. and W. Highland Park Ave., 9230 W. Highland Park Ave., Franklin
13	2,529,907.39	330,790.27	Northeast corner of intersection of sidewalks at northeast corner of intersection of Lake Pointe Dr. and Golden Lake Way, Franklin
14	2,529,625.06	328,389.62	Southwest corner of 90-degree angle in sidewalk, west side of Redwing Dr., at end of sidewalk south of Elm St., Franklin
15	2,531,246.58	332,114.73	Northeast corner of intersection of curbs at edge of east parking area, northeast corner of northernmost parking spot, east side of building north of Forest Park Middle School, 8225 W. Forest Hill Ave, Franklin
16	2,523,809.20	344,061.95	Northwest corner of intersection of sidewalks, northwest corner of intersection of Whitnall Edge Dr. and Whitnall Edge Ct., Franklin
17	2,522,520.76	343,185.75	South corner of acute intersection of sidewalks, located on east end of parking lot near northeast corner of Menards building, approx. 6455 W. Speedway Dr. and parking lot entrance, Franklin
18	2,522,858.51	341,971.73	Northeast corner of intersection of sidewalks, northwest corner of intersection of W. Cortez Rd. and S. Prairiewood Lane, Franklin
19	2,522,333.21	340,220.19	West corner of intersection of concrete driveway apron and top of curb, 7053 S. Fieldstone Ct., Franklin
20	2,520,268.17	337,874.65	Southeast corner of pavement, at south end of parking lot of building owned by MMSD, 11575 W. Forest Home Ave., Franklin
21	2,547,889.32	350,479.51	Southeast corner of intersection of sidewalks, southeast corner of intersection of S. 31st St. and W. Wanda Ave., Milwaukee
22	2,549,846.61	351,182.76	Northeast corner of intersection of sidewalks, northeast corner of intersection of W. Grange Ave. and S. 25th St., Milwaukee
23	2,550,435.83	349,849.42	Northwest corner of intersection of sidewalks, northwest corner of intersection of W. Parnell Ave. and S. 23rd St., Milwaukee
24	2,551,859.74	345,950.26	Northeast corner of intersection of sidewalks, northeast corner of intersection of W. College Ave. and S. 20th St., Milwaukee
25	2,553,554.70	346,310.16	Southwest corner of intersection of sidewalks, second walk west of entrances, south side of Park and Ride lot between lot and bus turn-around area at northeast corner of IH 94 and W. College Ave., Milwaukee

Point Number	Easting	Northing	Location Description
26	2,535,862.19	352,877.30	Northeast corner of intersection of sidewalks, northeast corner of intersection of S. 68th St. and W. Manchester Dr., Greendale
27	2,538,646.76	350,933.30	Northwest corner of north traffic island on east side of S. 60th St., intersection of W. Grange Ave. and S. 60th St., Greendale
28	2,541,402.20	348,248.63	Southwest corner of intersection of sidewalks, on grounds of Highland View Elementary School, southeast of the intersection of W. Ramsey Ave. and S. 51st St., west of parking lot that is parallel to W. Ramsey Ave., Greendale
29	2,543,792.03	348,064.27	Northeast corner of intersection of sidewalk and driveway (on N. 43rd St.), 4301 W. Ramsey Ave., Greendale
30	2,541,242.07	345,695.84	Northeast corner of intersection of sidewalks, northeast corner of intersection of S. 51st St. and W. College Ave., Greendale
31	2,566,040.11	359,431.83	Northeast corner of intersection of sidewalks, northeast corner of intersection of S. Iowa Ave. and E. Bolivar Ave., St. Francis
32	2,567,582.01	357,213.32	Northeast corner of intersection of sidewalks, northeast corner of intersection of S. Pennsylvania Ave. and E. Whitnall Ave., St. Francis
33	2,571,389.42	360,328.79	Southwest corner of pavement at southern end of S. Lipton Ave., St. Francis
34	2,571,319.95	356,368.53	Northwest corner of intersection of sidewalks, northeast corner of intersection of E. Barnard Ave. and Sweet Applewood Lane, Cudahy
35	2,574,075.96	357,923.19	Southwest corner of intersection of sidewalks, southwest corner of intersection of E. Armour Ave. and S. Swift Ave., Cudahy
36	2,527,701.03	361,160.35	Northwest intersection of sidewalk and driveway, first driveway west of S. 92nd St., northwest of intersection of W. Howard Ave. and S. 92nd St., Milwaukee
37	2,530,155.98	361,136.76	Northeast intersection of sidewalks, southeast corner of intersection of S. 85th St. and W. Howard Ave., Greenfield
38	2,529,747.00	363,132.32	Southwest corner of intersection of sidewalks, southwest corner of intersection of W. Warnimont Ave. and S. 86th St., Milwaukee
39	2,531,301.68	355,940.17	Bridge Point: Northeast corner of island at east bridge deck joint, overpass of W. Layton Ave. and W. Forest Home Ave., Greenfield
40	2,534,414.62	358,621.59	Southwest corner of intersection of sidewalks, southwest corner of intersection of W. Coldspring Rd. and S. 72nd St., Greenfield
41	2,517,136.55	360,221.24	Southeast corner of intersection of sidewalk and driveway, 12376 W. Waterford Ave., Greenfield
42	2,519,851.35	356,879.40	Southeast corner of intersection of sidewalks, southwest of intersection of W. Sunset Lane and S. 116th St., Greenfield
43	2,522,441.08	363,897.17	Inside corner of acute intersection of two sidewalks, south of intersection of Wollmer Rd. and S. 108th St., 3400 block of S. 108th St., West Allis
44	2,522,603.88	361,737.19	North inside corner of angle in sidewalk, northeast of intersection of S. 108th St. and W. Beloit Rd., Greenfield
45	2,522,469.94	357,472.41	Northeast corner of intersection of sidewalk and driveway at approximately 4441 S. 108th St., Greenfield
46	2,537,947.93	371,378.62	Northwest corner of intersection of sidewalks, northwest corner of intersection of W. Hayes Ave. and S. 61st St., West Allis
47	2,538,312.17	368,082.36	Northwest corner of intersection of sidewalks, northwest corner of intersection of W. Stack Dr. and S. 60th St., Milwaukee
48	2,540,987.71	367,170.69	Southwest corner of intersection of sidewalks, southwest corner of intersection of W. Stack Dr. and S. 51st St., Milwaukee
49	2,541,897.05	373,525.96	Southeast corner of intersection of sidewalk and driveway, 4725 W. Electric Ave., West Milwaukee
50	2,544,488.26	367,886.54	Intersection of westerly corner of sidewalks, west side of driveway, northwest side of W. Forest Home Ave., in front of Manitoba Elementary School, 4040 W. Forest Home Ave., Milwaukee
51	2,526,008.73	384,645.33	Bridge Point: South side of traffic island, at intersection with center pavement joint, bridge overpass of W. Wisconsin Ave. and USH 45, Wauwatosa
52	2,527,532.22	380,050.27	Southeast corner of sidewalks, east side of S. 92nd St., 520 S. 92nd St., Milwaukee
53	2,532,636.62	380,824.71	Intersection of east side of sidewalk and north edge of pavement, north side of parking lot off of Kearney St. at northeast corner of State Fair Park, Milwaukee

Appendix C (continued)

Point Number	Easting	Northing	Location Description
54	2,530,191.19	378,021.28	Southwest corner of intersection of sidewalks, northwest corner of intersection of S. 84th St. and W. Washington St., West Allis
55	2,534,205.35	379,291.19	Northwest corner of parking lot pavement, lot located southeast of intersection of W. Walker St. and S. 72nd St., West Allis
56	2,557,800.48	392,060.11	Northwest corner of intersection of sidewalks, northwest corner of intersection of W. Brown St. and N. 2nd St., Milwaukee
57	2,557,851.15	389,056.07	Southwest corner of intersection of sidewalks, east of intersection of Martin Luther King Jr. Dr. (N. 3rd St.) and W. Vliet St. (also known as Manpower Place), between east end of W. Vliet St. and Milwaukee River, on south side of W. Vliet St., Milwaukee
58	2,559,676.57	388,639.54	Northeast corner of intersection of sidewalks, northwest corner of intersection of E. Knapp St. and N. Jefferson St., Milwaukee
59	2,561,716.30	393,054.26	Southwest corner of intersection of sidewalks, southwest of intersection of N. Humboldt Ave. and E. Reservoir Ave., Milwaukee
60	2,562,496.50	386,929.93	Northeast corner of parking lot pavement, most easterly point of parking lot northeast of Milwaukee County War Memorial Center, 750 N. Lincoln Memorial Dr., Milwaukee
61	2,528,078.29	394,067.41	Inside corner of intersection of sidewalks, southwest corner of intersection of W. Wright Ave. and N. 89th St., Wauwatosa
62	2,532,291.29	393,012.18	Northeast corner of intersection of sidewalks, south side of Longfellow Middle School, northwest of intersection of W. North Ave. and N. 76th St., 7600 W. North Ave., Wauwatosa
63	2,530,524.91	387,644.21	Northwest corner of intersection of sidewalks, north side of Harwood Ave., office building at 8200 Harwood Ave., Wauwatosa
64	2,533,909.14	392,298.48	Southwest corner of intersection of sidewalks, southwest corner of intersection of W. Garfield Ave. and N. 72nd St., Wauwatosa
65	2,533,597.15	389,879.11	Inside corner of intersection of sidewalks, southwest corner of intersection of Harwood Ave. and Milwaukee Ave., Wauwatosa
66	2,519,387.77	389,781.04	Southeast corner of intersection of sidewalks, in front of Wauwatosa Police Department (1700 N. 116th St.), east of intersection of Walnut Rd. and 116th St, north side of Walnut Rd., directly south of building, Wauwatosa
67	2,520,854.78	387,118.94	Bridge Point: Bridge joint at south edge of pavement at sidewalk on south side, west of bridge, eastbound lane of bridge, overpass of W. Watertown Plank Rd. over railroad tracks and Underwood Creek, Wauwatosa
68	2,521,749.56	394,639.97	Top of curbs at intersection of north and east facing curbs, southwest corner of parking lot for Barnett Dermatology Center, approx. 2646 N. Mayfair Rd., Wauwatosa
69	2,521,691.14	390,236.56	Northeast corner of intersection of sidewalks, near the northeast corner of parking lot for Pick N Save, 1717 N. Mayfair Rd., Wauwatosa
70	2,522,969.67	386,351.09	Northwest corner of intersection of sidewalks, at southern driveway entrance to 10437 W. Innovation Dr., Wauwatosa
71	2,555,994.19	404,025.59	Northeast corner of intersection of sidewalks, near northwest corner of N. 6th St. and westbound on-ramp to W. Capitol Dr., Milwaukee
72	2,558,825.89	403,771.73	Top of curb intersection at the northwest corner of east parking lot, Aldi's Foods, 225 E. Capitol Dr., location is 12 parking spaces west of driveway entrance to parking lot from N. Richards St., Milwaukee
73	2,561,291.85	401,258.10	Northwest corner of intersection of sidewalk and alley, N. Weil St., about one-half block south of E. Keefe Ave., southeast corner of parking lot, approx. 3400 N. Weil St., Milwaukee
74	2,561,016.60	398,790.33	Northeast corner of intersection of sidewalks, northeast corner of intersection of E. Burleigh St. and N. Bremen St., Milwaukee
75	2,563,785.11	396,690.37	Northwest corner of intersection of sidewalks, near a path that leads west to the 50-yard line of the football field / athletic track, Riverside High School near Riverside Park, Milwaukee
76	2,535,817.39	401,073.85	Northeast corner of intersection of sidewalk and entrance drive, west entrance to parking lot for Dineen Park, approx. 6520 W. Keefe Ave. Parkway, Milwaukee
77	2,538,277.18	403,990.53	Intersection of west side of sidewalk and curb, along W. Capitol Parkway that winds through Midtown Center Shopping Complex, north of 5710 W. Capitol Dr., Milwaukee
78	2,540,327.68	401,797.32	Northeast corner of intersection of sidewalks, northwest corner of intersection of W. Nash Ave. and N. 51st St., Milwaukee

Appendix C (continued)

Point Number	Easting	Northing	Location Description
79	2,544,113.79	400,259.70	Northwest corner of intersection of sidewalks, northwest corner of intersection of W. Fond du Lac Ave. and N. 40^{th} St., Milwaukee
80	2,543,565.33	398,135.94	Southeast corner of intersection of sidewalks, in Sherman Park north of Milwaukee Boys and Girls Club building and south of tennis courts, 3000 N. Sherman Park Blvd., Milwaukee
81	2,535,239.78	409,165.61	Northwest corner of intersection of sidewalks, northwest of intersection of W. Fond du Lac Ave. and W. Hampton Ave., Milwaukee
82	2,539,005.44	411,853.37	Northwest corner of intersection of sidewalks at northwest corner of intersection of W. Villard Ave. and N. 55^{th} St., Milwaukee
83	2,542,028.33	411,450.65	Northeast corner of intersection of sidewalks, southeast corner of intersection of W. Eggert Place and N. 46^{th} St., Milwaukee
84	2,540,285.23	407,462.26	Intersection of east side of sidewalk and curb at northwest corner of W. Parkway Dr. and N. 51^{st} St., Milwaukee
85	2,542,661.98	406,597.29	Northeast corner of intersection of sidewalks, northeast corner of intersection of N. 44^{th} St. and W. Congress St., Milwaukee
86	2,556,916.90	412,778.40	Southeast corner of intersection of sidewalk and curb, west side of N. Mohawk Ave. north of intersection with W. Lexington Blvd., Glendale
87	2,558,574.45	409,410.42	Northwest corner of acute intersection of sidewalks, northwest corner of intersection of N. Anita Ave. and E. Hampton Ave., Whitefish Bay
88	2,559,826.03	413,786.87	Southwest corner of intersection of sidewalks, northwest corner of intersection of E. Birch Ave. and Hollywood Ave., Whitefish Bay
89	2,561,982.57	409,098.37	Intersection of sidewalk and pavement, east side of Cumberland Elementary School between Ardmore St. and N. Marlborough Dr., Whitefish Bay
90	2,563,280.71	406,992.63	Northeast corner of intersection of corner sidewalk and basketball court, sidewalk is southerly extension of sidewalk on east side of Larkin St., in playground northwest of Lake Bluff Elementary School, 1600 E. Lake Bluff Blvd., Shorewood
91	2,520,975.43	419,602.43	North angle point of sidewalk, west side of parking area for Milwaukee Seventh Day Adventist Church, 10900 W. Mill Rd., Milwaukee
92	2,519,487.30	418,651.34	Bridge Point: Northwest corner of bridge, most westerly point of expansion joint at pavement level, bridge for northbound exit ramp of USH 45 near Appleton Ave., Milwaukee
93	2,521,723.31	423,349.84	Bridge Point: Top of curb at north end of bridge parapet wall, east side of N. 107^{th} St. overpass of W. Fond du Lac Ave., Milwaukee
94	2,522,376.21	420,966.85	Northeast corner of intersection of sidewalks, north of intersection of W. Daphne St. and N. 105^{th} St., Milwaukee
95	2,520,147.79	417,233.74	Southeast corner of intersection of sidewalks, southeast of intersection of W. Kaul Ave. and N. 112^{th} St., Milwaukee
96	2,535,818.30	430,327.86	Inside corner of intersection of sidewalks, southeast of intersection of W. Bradley Rd. and N. 66^{th} St., Milwaukee
97	2,538,322.61	432,837.46	Westerly intersection of sidewalks between Dean Elementary School (8355 N. 55^{th} St.) and Algonquin Elementary School, off of W. Dean Ave., Brown Deer
98	2,537,638.53	426,273.15	Northwest intersection of sidewalks, northeast intersection of W. Hemlock St. and N. 60^{th} St., east of Brynwood Country Club, Milwaukee
99	2,541,593.64	430,557.39	Southwest corner of right angle corner of sidewalk, northwest intersection of W. Bradley Rd. and N. 47^{th} St., Milwaukee
100	2,538,652.24	430,476.98	Southwest corner of intersection of sidewalks, along north side of W. Bradley Rd. in front of Brown Deer Public Library, 5600 W. Bradley Rd., Brown Deer

NOTE: Points are measured on the Wisconsin State Plane Coordinate System, South Zone, North American Datum of 1927. All units expressed in survey feet.

Source: SEWRPC.

Appendix D

CALIBRATION TEST AND DEMONSTRATION OF USE OF GPS

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Appendix D

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

OBJECTIVE

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

PROCEDURES AND RESULTS

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

1. Identify SEWRPC control survey stations in the area to be surveyed and conduct field reconnaissance and recovery of control survey stations to be held as "fixed" positions with published SEWRPC NAD 27 State Plane Coordinates and NGVD 29 elevations. For the demonstration this involved the recovery of four monumented control survey stations to be held "fixed" and five other monumented stations in each of the two sections for which position and elevation values were to be established. Copies of SEWRPC "Record of U.S. Public Land Survey Control Station" sheets were obtained for all of the monumented corners concerned. These sheets provided the NAD 27 published State Plane Coordinate values and NGVD 29 elevations for the monumented corners. The tie distances to the witness marks concerned were measured and compared to the recorded tie distances for each corner to verify that the monument marking the corner had not been disturbed. The elevation of the monuments concerned were checked by differential level survey from attendant referenced bench marks and compared to the published elevations.

2. Best practice dictates that at least four fixed control stations should be used in a GPS field calibration. The four control stations should be located outside of, but as near as practicable to, the points for which coordinates and elevations are to be determined. The published coordinates and elevations of the fixed control stations, along with a station identification number, should then be uploaded to the GPS instrument data collector through the use of a previously prepared ASCII or text file. This was done for the eight fixed control stations involved in the demonstration. At least four fixed station control stations should be used in a GPS field calibration for horizontal control and at least four should be used for vertical—elevation or orthometric height—control. The horizontal and vertical "calibration" does not need to be on the same stations for the horizontal and vertical "calibration."

3. The field operation was initiated by connecting the GPS unit to the WisDOT CORS network computer servers using a cellular telephone equipped with Bluetooth technology. Once the connection had been established, the GPS unit was ready to begin the initialization sequence. In the initialization

sequence the GPS unit collected information from available satellites to orient the unit to its initial location and orientation relative to the NAD 83 (2007) and NAVD 88 (2007) datums. It is correct to initialize the GPS unit on the first station occupied. However, for safety, or other reasons, the initialization need not occur on a known point.

4. Following initialization, the first fixed control survey station in the survey area concerned was occupied and the receiver antenna leveled. For the initial observation the unit and the observer face approximately north. During a station occupation it is possible to view certain data on the collector screen. These data included the number of satellites available during the observation; the strength and quality of the data being received from the available satellites—known as the positional dilution of position (PDOP) values; and the status of the operation of the communication link. The accuracy of the measurements is dependent upon the GPS antenna being carefully centered and leveled over the point being observed, and upon the antenna height above the occupied survey station being accurately measured. The later is usually done by use of a mounting pole having a fixed predetermined length, or by use of a graduated, extendable mounting pole. Built in software uses the input antenna height to compute the position of the occupied monument instead of the position of the receiving antenna. Although sequence is a matter of efficiency and preference, in the demonstration the first fixed control survey stations occupied were the Northwest corner of each of the sections concerned.

5. An initial set of measurements was completed and the data were stored in the collector. The GPS unit was then rotated so that the observer’ s position changed to face approximately south and a second set of measurements was obtained in the interest of redundancy and verification. Two sets of measurements were obtained in this way at each of the fixed control survey stations for each section concerned. This observational procedure was followed at each of the two initial and each of the attendant three fixed stations for each section included in the demonstration.

6. Upon completion of the occupation and observations at each of the four fixed control stations for a section, the GPS unit was considered to be calibrated to the “local” coordinate system, and vertical datum, in the case of the demonstration, the NAD 27 SPC system and the NGVD 29 datum. Using the now calibrated instrument, the four quarter-section corner monuments and the center of section monument for which NAD 27 coordinate values and NGVD 29 elevation values were to be determined were then occupied and the observed data stored in the data collector.

   The measurements obtained on each monument were paired with the corresponding known coordinates using the software incorporated in the data collector. The information generated from these data, is used to generate a localized projection and the user is presented with residuals for each of the pairings. The user can evaluate whether the solution meets the required level of horizontal and vertical accuracy of each point at this time. If necessary, individual horizontal and vertical points can be removed from the calculation in order to obtain a better fit, horizontally, vertically, or both.

The foregoing survey procedure was carried out in Sections 10 and 12 in Township 6 North, Range 20 East. The results are provided in Tables D-1 through D-4.

If a survey extends over a significant period of time, the continued validity of the initial calibration should be periodically checked. This involves returning to one of the initial calibration points, or to a point determined subsequent to a calibration, and noting that the repeat observation values are within the tolerance of the application. Any time a “check” fails to meet the determined tolerance, the system should be recalibrated. Good practice would include performing “checks” at the end of work each day on each project. Checks should not be postponed beyond a reasonable time limit.

CONCEPTS

The computations that permit the GPS unit to convert 3-D measurements referenced to the NAD 83 (2007) to NAD 27 SPC, are preprogrammed and carried out in the data collector component of the unit. Conceptually, the calibration process, in effect, fits a pseudoplane and attendant coordinates to the curved surface of the earth at the survey site. After the initialization step orients the instrument with respect to the latitude and longitude of the initially occupied fixed station referenced to NAD 83 (2007), and the control values referenced to the desired datums are entered into the data collector, the unit, through occupation of the remaining three fixed stations, adjusts the pseudoplane and attendant grid to best fit the entered coordinates on the desired datum. The unit then provides what are, in effect, pseudo State Plane Coordinates computed on the plane surface.

More specifically, in GPS surveys conducted within a CORS network, after calibration to known control points, coordinate positions of unknown points are calculated utilizing vectors from known nearby control points. The coordinate position of an unknown point is then calculated utilizing vectors from the nearby known points. The NAD 83 (2007) geocentric X/Y/Z coordinates of the nearby stations are known and the "error" of the GPS measured value at the known station is determined based on observations at CORS stations. The "error" is then used to determine the corrector to be applied to the GPS measured value at the unknown station. The vectors between the position of the known station and the corrected measured value at the unknown station are computed in terms of the relative $\Delta X/\Delta Y/\Delta Z$ components by utilizing the relative observed positions of the unknown points with respect to the given CORS values. Although the $\Delta X/\Delta Y/\Delta Z$ components of each vector are actually computed in the WGS 84 coordinate system, the results are expressed as NAD 83 (2007) coordinate differences because, for practical purposes on local networks, the WGS 84 $\Delta X/\Delta Y/\Delta Z$ components are the same as in the NAD 83 (2007). The origins of the WGS 84 and NAD 83 datums are slightly different but, for local networks, the $\Delta X/\Delta Y/\Delta Z$ and related vector values are almost identical. Therefore, the NAD 83 position of each unknown point is computed by adding the NAD 83 vector components to the known NAD 83 (2007) geocentric X/Y/Z coordinates of the nearby known stations.

In a network, multiple vectors are used to compute the position of an unknown point, the difference in the multiple positions obtained being resolved by a least squares adjustment which also models corrections needed to give the best possible solution. The satellite signals used to determine the vectors from each known station to the unknown points include errors inherent in satellite positioning such as clock time, ionosphere effects, and uncertainties in the satellite orbits. Although such errors are typically quite small the CORS stations provide a combined set of "corrections" to be applied in real time by each roving unit. Therefore, the GPS receiving unit—the rover—must be in communication with the CORS network through a central "server" via the Internet using cell phone technology. This communication is essential when using the WI-HMP RTN—the WISCORS network.

Using the RTN as described determines geocentric X/Y/Z NAD 83 (2007) coordinates for the station occupied. Latitude, longitude, and ellipsoid height are computed from those X/Y/Z values and, by user choice, Wisconsin South Zone NAD 83 (2007) State Plane Coordinates are computed from the latitude and longitude. Obtaining NAD 27 State Plane Coordinates for the same point involves either application of the bidirectional transformation parameters as described in this report or by utilization of the calibration procedure described in this Appendix.

It should be noted that in the State Plane Coordinate system—whether based upon NAD 83 (2007) or the NAD 27 datums—the coordinate positions are expressed as grid coordinates on the plane provided by the system projection. Inverse computations between known grid coordinate positions, therefore, provide grid distances. If ground level distances are required, the grid distances can be readily converted to ground level distances by application of the combination factor—the product of the scale factor and the sea level reduction factor—provided by the Commission in SEWRPC Technical Report No. 7, Third Edition, *Horizontal and Vertical Survey Control in Southeastern Wisconsin,* August 1996. These factors provide the reductions relative to mean sea level rather than to an ellipsoid of reference. The factors are provided for the centers of six - two by three - section areas within each survey township within the seven-county Region. The factors are also available on the Commission's website.[1]

This process is relatively straight-forward with respect to the computation and provision of the horizontal position values. When using the RTN, the NAD 88 (2007) elevation for a surveyed point is obtained from the ellipsoid height by applying the current geoid model as promulgated by the NGS―GEOID09. In order to obtain elevations on the NGVD 29 datum, either the appropriate bidirectional transformation procedure or the calibration procedure described herein should be used. When using the bidirectional direct modeling method, the NAD 83 (2007) State Plane Coordinates are required as input along with the elevation being transformed―either NAVD 88 (2007) to NGVD 29 or vice versa. If elevations are being determined by the calibration procedures described herein, the vendor proprietary calibration software models, in a best fit scenario, the field observed height differences to the elevation differences defined by the control point elevations input by the user. These procedures make it possible to utilize GPS instrumentation to obtain accurate elevations on NGVD 29 throughout the seven-county Region.

For higher order work and applications, there is no substitute for re-survey on the datum of choice. The procedure utilized in the demonstration survey as herein described, is recommended for use whenever higher orders of survey accuracy relating RPC and HMP positions are required than can be provided by the application of the data transformation procedures provided in this report. In utilizing the procedure it is important to determine that the GPS antenna is positioned so that clear obstruction-free sights exist to the available satellites. If a "free" station is located in an area where interference with the satellite signals may exist—such as in a wooded area, near high-rise buildings, near high voltage transmission lines, or next to a chain-link fence—it may become necessary to utilize conventional survey techniques to carry the coordinates and elevations from a supplementary GPS station located in a nearby obstruction-free area to the free station concerned.

EQUIPMENT AND CREW, DATE OF SURVEY, WEATHER CONDITIONS

The GPS equipment used for this demonstration was provided by Mr. Terrance J. Lueschow, RLS, of Seiler Instruments and consisted of a Trimble R-8 Model 3 Receiver, a TSC2 Data Collector, and Trimble Geomatics software package. The test was conducted on Wednesday, February 17, 2010, under cloudy skies and an average temperature of about 30ºF. The field crew consisted of Mr. Lueschow, Mr. Donald P. Simon, RLS, Southeastern Wisconsin Regional Planning Commission staff, and Mr. Andrew J. Traeger, CSTIII, also of the Southeastern Wisconsin Regional Planning Commission staff.

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[1]*It is technically more correct to use a combination scale and elevation factor, which provide the reduction relative to the ellipsoid of reference, when working with NAD 83 (2007) coordinates. However, based upon use of equation (6) in Burkholder (2004), it can be shown that the difference in using the combination scale and elevation factor in place of the combination scale and sea level factor promulgated by SEWRPC is less than 1:200,000 in the seven-county SEWRPC Region. Therefore, continued use of the combination scale and sea level reduction is acceptable within the Region.*

Table D-1

COMPARISON OF PUBLISHED NAD 27 COORDINATE VALUES TO PSEUDO NAD 27 COORDINATE VALUES OBTAINED USING GPS CALIBRATION PROCEDURE WITHIN SECTION 10, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NAD 27 Published Coordinates		NAD 27 Coordinate Values Obtained Using GPS Calibration Procedure		Difference Between NAD 27 Published and GPS Calibration Procedure Values	
		Northing Feet	Easting Feet	Northing Feet	Easting Feet	Northing Feet	Easting Feet
2101[a]	6-20 NW-10	371,215.630	2,506,072.820	- -	- -	- -	- -
2102	6-20 N-10	371,084.070	2,503,470.010	371,083.905	2,503,470.014	-0.165	0.004
2103[a]	6-20 NW-10	370,974.360	2,500,857.840	- -	- -	- -	- -
2104	6-20 C-10	368,443.110	2,503,478.160	368,443.059	2,503,478.073	-0.051	-0.087
2105	6-20 E-10	368,556.800	2,506,108.070	368,556.789	2,506,108.071	-0.011	0.001
2109[a]	6-20 SE-10	365,899.260	2,506,153.990	- -	- -	- -	- -
2110[a]	6-20 SW-10	365,678.930	2,500,819.830	- -	- -	- -	- -
2113	6-20 W-10	368,330.000	2,500,827.260	368,329.959	2,500,827.230	-0.041	-0.030
2114[b]	6-20 S-10	365,802.790	2,503,483.210	365,803.061	2,503,483.018	0.271	0.192
					Mean	**0.001**	**0.016**
					Standard Deviation	**0.162**	**0.105**

[a]*Monumented Control Station Coordinate value held as fixed.*

[b]*Monumented Corner located near chain link fence. Probable multipath of satellite signal.*

Source: SEWRPC.

Table D-2

COMPARISON OF PUBLISHED NAD 27 COORDINATE VALUES TO PSEUDO NAD 27 COORDINATE VALUES OBTAINED USING GPS CALIBRATION PROCEDURE WITHIN SECTION 12, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NAD 27 Published Coordinates		NAD 27 Coordinate Values Obtained Using GPS Calibration Procedure		Difference Between NAD 27 Published and GPS Calibration Procedure Values	
		Northing Feet	Easting Feet	Northing Feet	Easting Feet	Northing Feet	Easting Feet
2106	6-20 C-12	368,755.320	2,514,149.760	368,755.304	2,514,149.984	-0.016	0.224
2107	6-20 E-12	368,802.940	2,516,852.080	368,802.957	2,516,851.982	0.017	-0.098
2108[a]	6-20 SE-12	366,157.000	2,516,834.520	- -	- -	- -	- -
2111[a]	6-20 NE-12	371,475.330	2,516,869.030	- -	- -	- -	- -
2112[a]	6-20 NW-12	371,364.620	2,511,433.760	- -	- -	- -	- -
2115[b]	6-20 N-12	371,427.630	2,514,150.270	371,428.156	2,514,150.858	0.526	0.588
2116	6-20 S-12	366,083.260	2,514,150.960	366,083.234	2,514,151.141	-0.026	0.181
2117	6-20 W-12	368,685.050	2,511,456.710	368,684.934	2,511,456.877	-0.116	0.167
2118[a]	6-20 SW-12	366,025.240	2,511,468.700	- -	- -	- -	- -
					Mean	**0.077**	**0.212**
					Standard Deviation	**0.256**	**0.245**

[a]*Monumented Control Station Coordinate value held as fixed.*

[b]*Monumented Corner located in wooded area. Probable multipath of satellite signal.*

Source: SEWRPC.

Table D-3

COMPARISON OF NGVD 29 ELEVATION VALUES OBTAINED FROM DIFFERENTIAL LEVELING WITH ELEVATION VALUES OBTAINED DURING THE GPS CALIBRATION PROCEDURE FOR SECTION 10, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NGVD 29 Elevation Derived from Differential Leveling	Elevation Derived During GPS Calibration Procedure	Difference
2101[a]	6-20 NE-10	864.205	- -	- -
2102	6-20 N-10	845.693	845.751	0.058
2103[a]	6-20 NW-10	866.418	--	- -
2104	6-20 C-10	867.408	867.393	-0.015
2105	6-20 E-10	891.122	891.129	0.007
2109[a]	6-20 SE-10	863.383	- -	- -
2110[a]	6-20 SW-10	868.444	- -	- -
2113	6-20 W-10	888.024	887.969	-0.055
2114[b]	6-20 S-10	882.691	882.671	-0.020
			Mean	**-0.005**
			Standard Deviation	**0.044**

[a]*Monumented Control Station elevation value held as fixed.*

[b]*Monumented Corner located near chain link fence. Probable multipath of satellite signal.*

Source: SEWRPC.

Table D-4

COMPARISON OF NGVD 29 ELEVATION VALUES OBTAINED FROM DIFFERENTIAL LEVELING WITH ELEVATION VALUES OBTAINED DURING THE GPS CALIBRATION PROCEDURE FOR SECTION 12, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NGVD 29 Elevation Derived from Differential Leveling	Elevation Derived During GPS Calibration Procedure	Difference
2106	6-20 C-12	793.046	793.057	0.011
2107	6-20 E-12	760.684	760.644	-0.040
2108[a]	6-20 SE-12	772.039	- -	- -
2111[a]	6-20 NE-12	758.648	- -	- -
2112[a]	6-20 NW-12	832.648	- -	- -
2115[b]	6-20 N-12	783.491	783.873	0.382
2116	6-20 S-12	813.615	813.682	0.067
2117	6-20 W-12	841.825	841.785	-0.040
2118[a]	6-20 SW-12	865.090	- -	- -
			Mean	**0.076**
			Standard Deviation	**0.122**

[a]*Monumented Control Station elevation value held as fixed.*

[b]*Monumented Corner located in wooded area. Probable multipath of satellite signal.*

Source: SEWRPC.