



LIDAR QUALITY ASSESSMENT REPORT

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1 PROJECT OVERVIEW

Douglas County, WI procured services from Pictometry International Corp. to acquire LiDAR and Aerial photos for the entire County in the Fall of 2016. Douglas County then contracted with Houston Engineering, Inc. (HEI) to conduct a vertical accuracy quality assessment for the bare earth LiDAR product. The quality assessment is delivered as a report that describes the vertical accuracy comparison between the bare earth LiDAR and independent survey checkpoints.

The purpose of the report is to validate the accuracy of the bare earth LiDAR deliverable meets the vertical RMSE_(z) specifications for the project. HEI was only contracted to complete a vertical accuracy assessment and compile the report for the bare earth LiDAR product. Douglas County separately contracted with HEI for the independent survey checkpoints to use in the assessment. HEI's survey report is included as Appendix C. This report outlines the methodology and results of the vertical accuracy assessment by comparing the elevations between the bare earth LiDAR product and survey checkpoints. No other quality assurance was conducted as part of this contract by HEI.

2 VERTICAL ACCURACY ASSESSMENT CONSIDERATIONS

2.1 REFERENCES AND APPLICABLE METHODS

The processes and methods used to QA the vertical accuracy of the bare earth LiDAR products are largely based upon guidance established by various federal agencies/entities including the Federal Emergency Management Agency (FEMA) and the Federal Geographic Data Committee (FGDC). Portions of the following references form the basis for the QA process:

- National Geospatial Program Lidar Base Specification, Version 1.2, Released November, 2014, Chapter 4 of Section B, USGS, 7-9 p.
- American Society for Photogrammetry and Remote Sensing (ASPRS) Guidelines, Vertical Accuracy Reporting for LiDAR Data, Version 1.0, Released May 24, 2004, ASPRS LiDAR Committee, 20 p.
- Federal Geographic Data Committee, 1996. Content Standards for Digital Geospatial Metadata (version 2.0), FGDC-STD-001-1998: Washington, D.C., Federal Geographic Data Committee, 9 p.
- Federal Geographic Data Committee, 1998, Part 3: Geospatial Positioning Accuracy Standards, FGDC-STD-007.3-1998: Washington, D.C., Federal Geographic Data Committee, 25 p.
- Federal Emergency Management Agency, 2003, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying [February 2002], 57p.
- Federal Emergency Management Agency, 2003, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix 4B: LIDAR Specifications for Flood Hazard Mapping, 8p.

The QA process included select portions from these references primarily to determine nonvegetative and vegetative vertical accuracy of the bare earth product.

2.2 PERFORMANCE SPECIFICATIONS FOR LIDAR PRODUCTS ESTABLISHED BY THE CONTRACT

The County provided the specifications for the vertical accuracy of the bare earth products must meet the USGS QL2 absolute vertical accuracy for nonvegetated of RMSE(z) of ≤ 10.0 cm.



Although several LiDAR products are generated by the current collection effort, this QA report pertains solely to the vertical elevations of the bare earth products.

2.3 QUALITY ASSESSMENT PROCESS

The QA process is intended to assess whether the LiDAR deliverables meets the following criteria:

- The final products are delivered in Douglas County coordinates with elevation values in NAVD 1988 datum (orthometric heights);
- Files are named correctly in accordance with the tiling and collection area scheme and are not corrupt;
- Investigation for the presence of blunders based upon the survey checkpoints. Blunders are defined as a difference between the measured checkpoint elevation and the elevation determined from the bare earth products which exceeds 3 times the standard deviation (as defined by ASPRS Guidelines) as an indicator of potential for systematic error;
- Descriptive statistics computed by land use and reporting groups for the elevation difference between the checkpoint elevation and the LiDAR elevation to verify normality assumptions used when computing the root mean square error (RMSE(z)) for nonvegetative vertical accuracy (NVA);
- Vertical accuracy expressed as:
 - NVA for those check points in classes 1 (Open, bare earth, low grass) and 2 (Urban Areas) as defined by the USGS LiDAR Base Specifications;
 - Vegetated vertical accuracy (VVA) for those check points in classes 3 (Tall grass, tall weeds and crops), 4 (Brush lands and short trees) and 5 (Forested areas) as defined by the USGS LiDAR Base Specifications;
 - Consolidated vertical accuracy computed across land use categories and expressed as the 95th percentile error value; and
 - Absolute difference between the checkpoint and LiDAR elevation.

2.4 COLLECTION OF KNOWN ELEVATIONS IN THE FIELD

Known elevations (i.e., checkpoints) within five (5) land use categories were collected using the methodology described in Appendix C. Independent survey checkpoints were collected on flat ground and documented with a photo of the location. Checkpoints counts as shown in Figure 1 were collected within the following land use categories:

- Low grass, bare earth;
- High grass, weeds, crops;
- Brush, low trees;
- Forested; and
- Urban – developed.

Land use was based on the National Land Cover Dataset (2014) as shown in **Figure 2**. Land use categories are consistent with those recommended by various reference documents as described within Section 2.1.

A minimum of 20 checkpoints were collected in the nonvegetative and vegetated reporting category because $RMSE_{(z)}$ computations are based on the assumption of a normality of the errors.

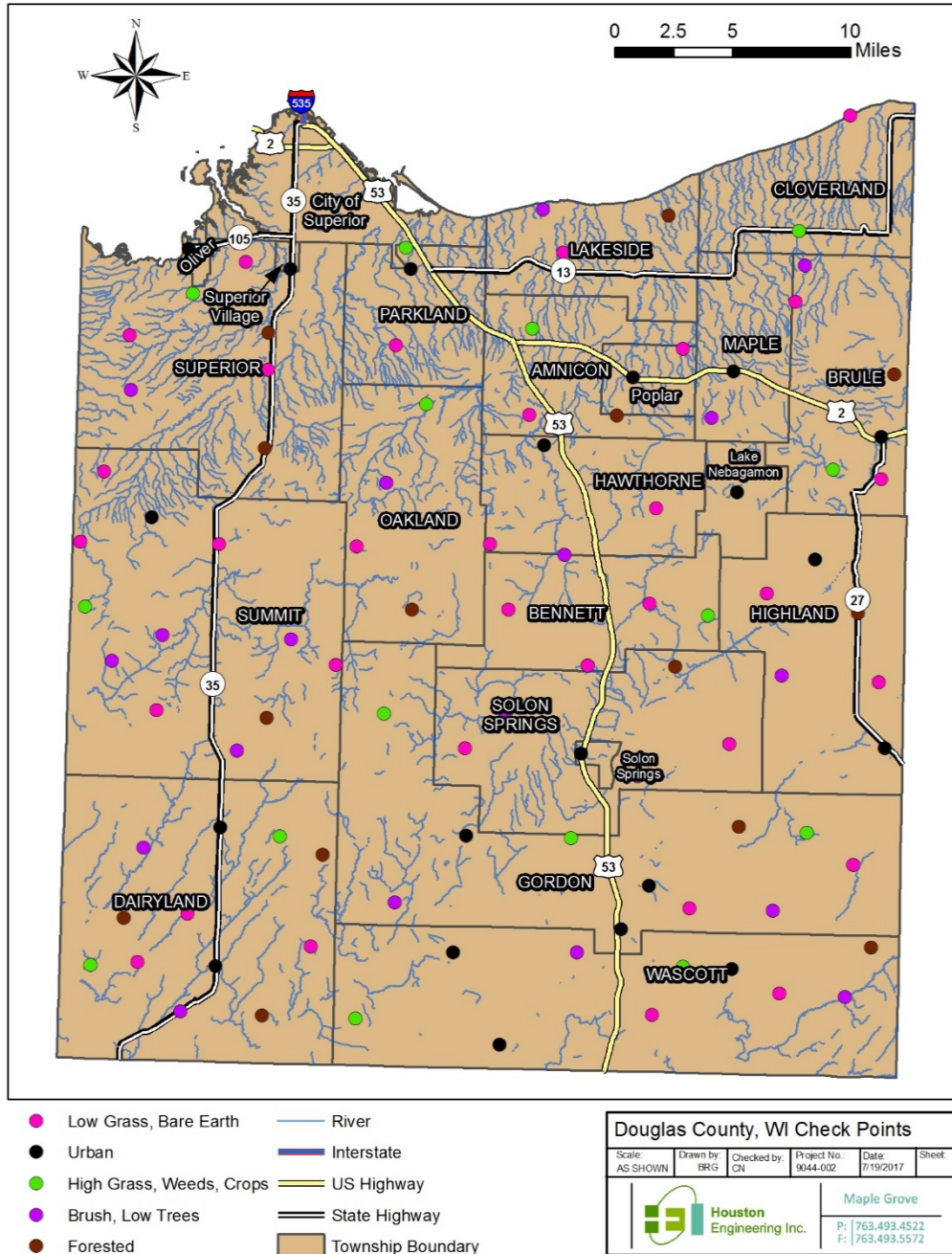
There is a presumption that the independent survey checkpoints elevation values are free of error and that discrepancies between the LiDAR and checkpoint elevations are attributable to the LiDAR



technology. This assumption is considered valid provided the technology used to obtain the checkpoint elevations yield accuracy at least three times greater than the expected accuracy of LiDAR. It should be recognized that the checkpoint survey is in fact not free of error.

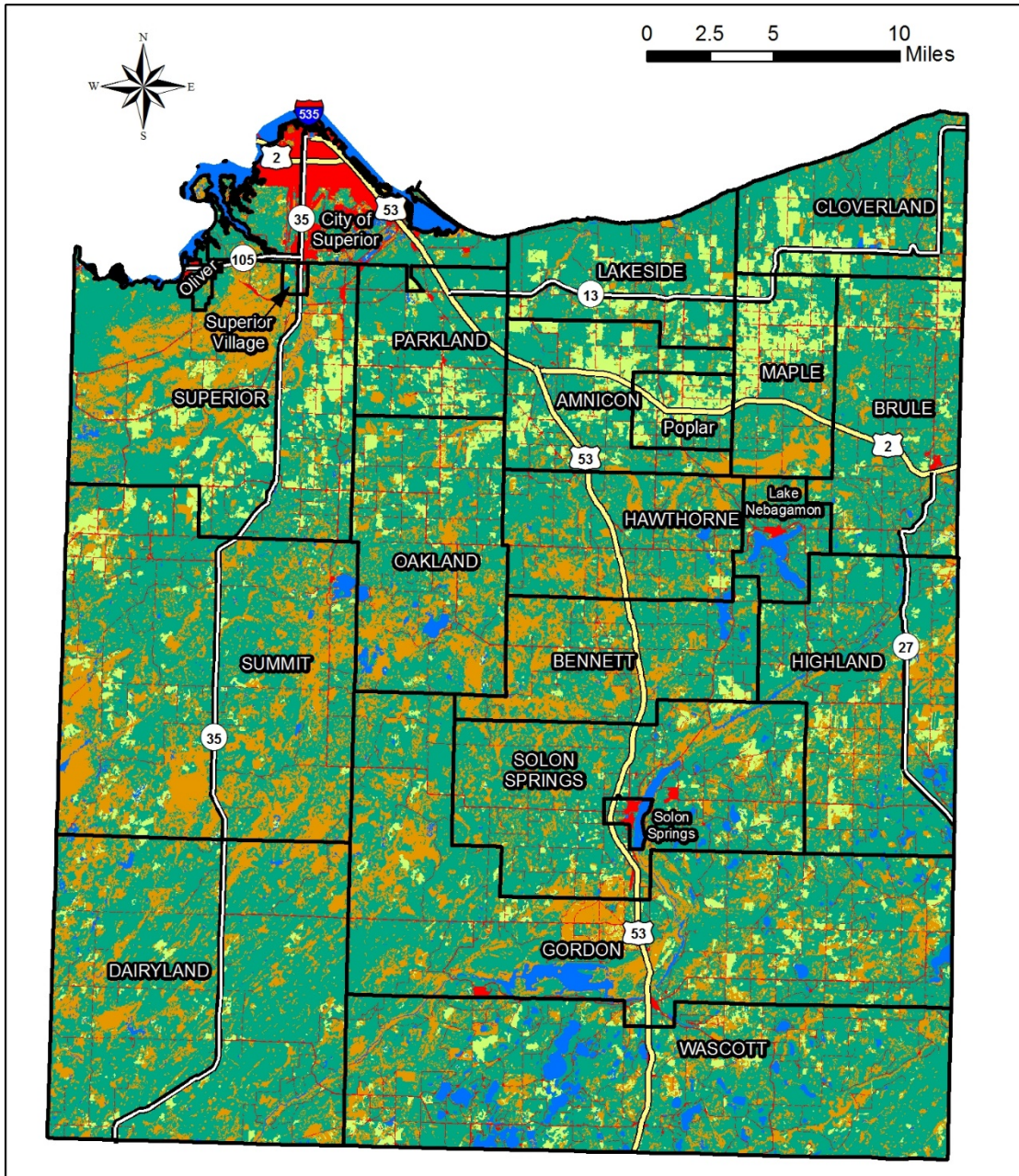


Figure 1: Check Points Within Douglas County, WI



Land Use	Reclassified Group	Number of Points	LCD Proportion of Area (%)
1	Low Grass, Bare Earth	32	0.0
2	Urban	19	5.3
3	High Grass, Weeds, Crops	15	7.8
4	Brush, Low Trees	19	22.6
5	Forested	14	60.9
*Area classified as water makes up final 3.3%		99	96.7

Figure 2: Land Use Within Douglas County, WI



- Open Water
- Urban
- Low Grass, Bare Earth
- Forested
- Brush, Low Trees
- High Grass, Weeds, Crops
- Interstate
- US Highway
- State Highway
- Township Boundary

Douglas County NLCD (2014)					
Scale: AS SHOWN	Drawn by: BRG	Checked by: CN	Project No.: 9044-002	Date: 7/19/2017	Sheet:
Houston Engineering Inc.				Maple Grove P: 763.493.4522 F: 763.493.5572	

Land Use	Land Use Description	Sq. Miles (NLCD area)	LCD Proportion of Area (%)
1	Low Grass, Bare Earth	0.4	0.0

Land Use	Land Use Description	Sq. Miles (NLCD area)	LCD Proportion of Area (%)
2	Urban	71.0	5.3
3	High Grass, Weeds, Crops	105.3	7.8
4	Brush, Low Trees	304.0	22.6
5	Forested	818.0	60.9
6	Open Water	44.0	3.3
		1342.3	100.0

2.5 COMPUTING THE RMSE_(z)

The vertical accuracy calculations were generated using Merrick’s MARS and Excel spreadsheets. The LiDAR surface elevations are calculated by interpolating from the bare earth LAS files delivered by the vendor. A Triangular Irregular Network (TIN) is created around each checkpoint, using LiDAR points. Then the triangle that covers the survey checkpoint location horizontally is selected. The location on the surface of this triangle that matches the sample location then provides the elevation. This elevation is a linear interpolation of the elevations of the three triangle vertices; or more simply, it is the point in 3D on the TIN triangle at the sample location’s X and Y. The RMSE_(z) is computed as:

$$RMSE_{(z)} = \text{Sqrt} \left[\frac{\sum (Z_{\text{Lidar}(i)} - Z_{\text{checkpoint}(i)})^2}{n} \right]$$

where n is the total number of checkpoints and i represents any given checkpoint

2.6 CRITERIA FOR ACCEPTANCE

The sole criteria for acceptance of the LiDAR product is RMSE_(z) of <= 10.0 cm or less in the nonvegetated reporting class for the bare earth data as provided by Douglas County. Any other issues that are observed by the assessment will be reported directly to the County for informational purposes.

3 VERTICAL QUALITY ASSESSMENT RESULTS

3.1 PROJECT AREA DESCRIPTION

High grass, weeds, and crops comprise approximately 7.8% of the land use within the County. Urban (5.3%), forested (60.9%), low grass and bare earth (<1.0%), and brush and low trees (22.6%) comprise the remaining land uses within the project area (**Figure 2**). Ninety-nine checkpoints were collected within the project area and used during completion of the QA process (**Figure 1**).

3.2 RESULTS

3.2.1 VERTICAL ACCURACY

Table 1 shows the RMSE_(z) derived from checkpoints across various reporting groups. The reporting groups included:

- By individual land use class;
- Nonvegetated vertical accuracy (NVA) for those check points in classes 1 (Open, bare earth, low grass) and 2 (Urban Areas);
- Vegetated vertical accuracy (VVA) for those check points in classes 3 (Tall grass, tall weeds, and crops), 4 (Brush lands and short trees) and 5 (Forested areas); and
- Consolidated vertical accuracy computed across land use categories.

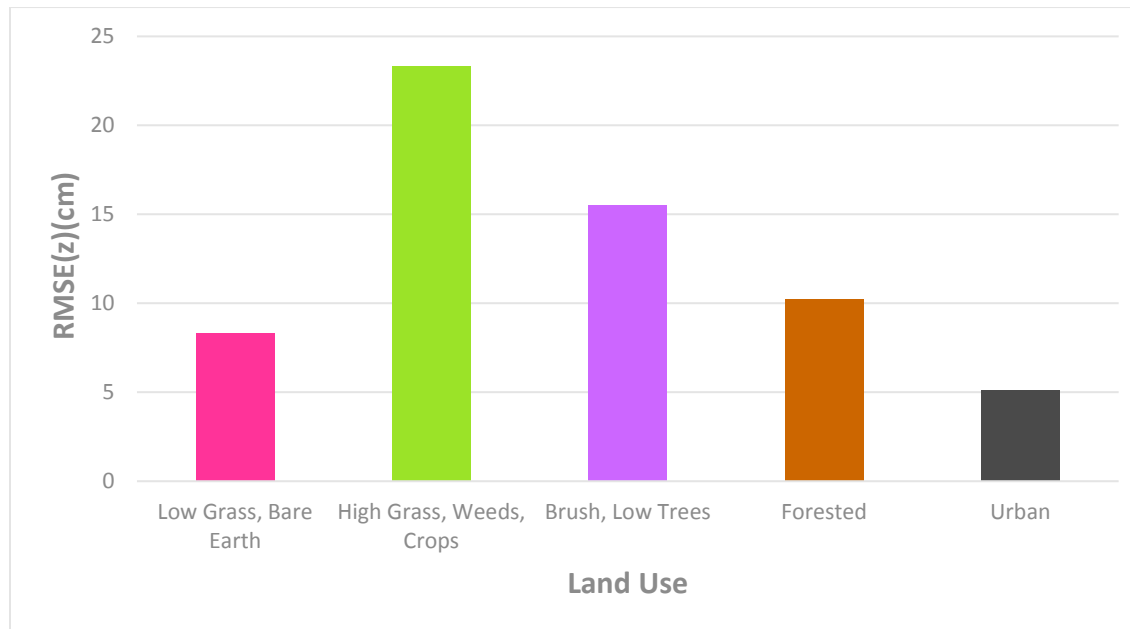
Table 1: Vertical Accuracy Descriptive Statistics by Reporting Groups

Checkpoint Reporting Group	# of Check Points	Mean Absolute Difference (cm)	Skew	Std Dev. (cm)	Min Absolute Difference (cm)	Max Absolute Difference (cm)	Mean Difference (cm)	95% Confidence Interval Value (cm)	95% Percentile Value	RMSE(z)(cm)
Low Grass, Bare Earth	32	6.7	0.6	4.9	0.2	17.7	-4.5	1.8	15.4	8.3
High Grass, Weeds, Crops	15	18.4	1.9	14.7	5.4	60.4	-18.4	8.1	44.6	23.3
Brush, Low Trees	19	12.9	0.5	8.8	1.5	30.2	-12.2	4.2	27.4	15.5
Forested	14	8.3	1.2	6.2	0.7	23	-6.7	3.6	19.4	10.2
Urban	19	3.5	1.6	3.8	0.2	13.1	-0.5	1.8	11.8	5.1
Nonvegetative(NVA)	51	5.5	0.9	4.8	0.2	17.7	-3	1.3	13.8	7.2
Vegetative (VVA)	48	13.3	2	11	0.7	60.4	-12.5	3.2	30.2	17.2
Consolidated (All Points)	99	9.3	2.4	9.2	0.2	60.4	-7.6	1.8	25.4	13

1. **Appendix A** shows the difference in elevation between each survey checkpoint and the elevation derived from the LiDAR bare earth TIN.

Calculation of the $RMSE_{(z)}$ assumes that the vertical errors are normally distributed with a mean of zero. The mean difference is -7.6 cm and the skewness coefficient is 2.4 cm which indicates the vertical errors are negative and skewed left. **Table 1** shows that the normality of the errors seems marginal for the errors within the project area based on skewness. **Figure 3** graphically represents the individual land use grouping $RMSE_{(z)}$ values.

Figure 3: $RMSE_{(z)}$ by Land Class



The actual difference between the measured checkpoint elevation and the elevation derived from the LiDAR TIN is a residual. **Figure 4** shows an analysis of the residuals for all checkpoints.

Figure 4: Histogram of Residual Differences

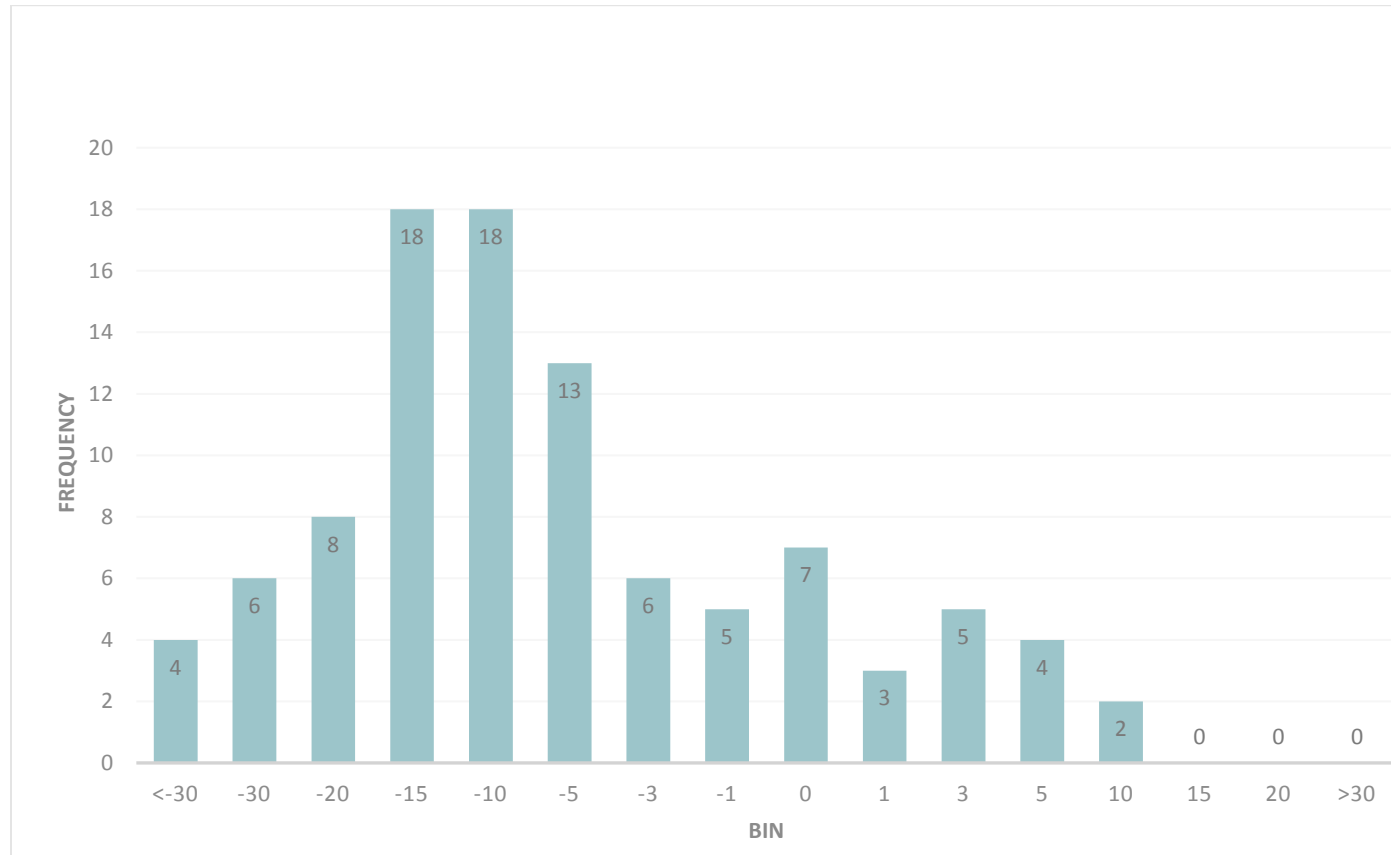
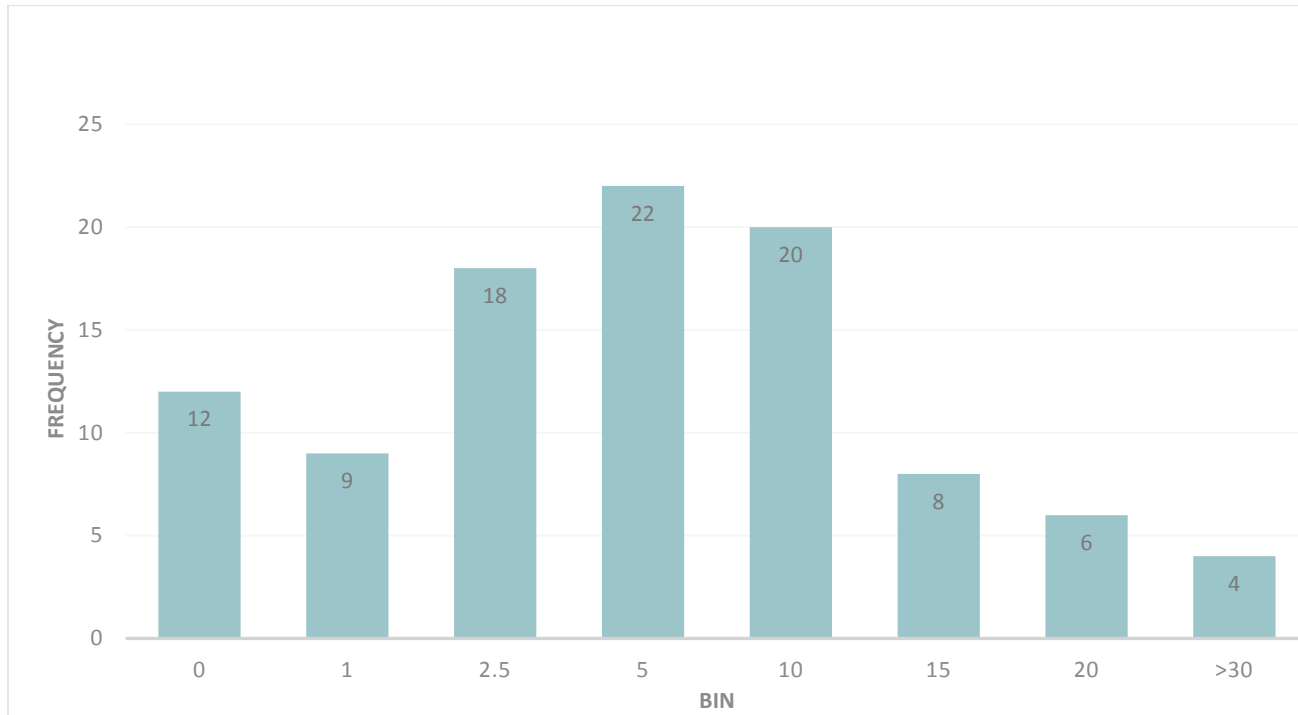


Figure 5 shows the absolute values of the residuals. This figure shows that the absolute value (and therefore errors), tend to be normally distributed.

Figure 5: Histogram of Absolute Value of Residual Differences



3.2.2 CONCURRENCE WITH THE SPECIFICATION

This quality assurance review shows that the nonvegetated $RMSE_{(z)}$ of **7.2** cm determined for the bare earth LiDAR product (Filtered LAS files) is equal to or **less than** the specification of ≤ 10.0 cm and therefore **achieves** the required specification. Figure 4 shows that a majority of the checkpoints elevations were lower than the lidar bare earth elevations, specifically in the vegetated reporting classes. This may suggest the survey rod in the checkpoint collection was able to get to the hard ground where the LiDAR sensor did not penetrate thick vegetative cover such as matted down grass and fallen leaves. **Appendix A** shows the difference between each checkpoint elevation and the elevation derived from the TIN derived from the bare earth LiDAR data.

Report/Survey Certification:

I hereby certify that this survey, plan, or report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of Wisconsin.



Date: August 7, 2017

Bart Schultz, P.E.

WI License No. 25148

4 APPENDICES

4.1 APPENDIX A: VERTICAL ELEVATION DIFFERENCES BY SURVEY CHECKPOINTS

Douglas County Survey Checkpoints (Douglas County Coordinate System (FT))					LiDAR Elevations		Results	
Point ID	Land Use Class	X Coord	Y Coord	Z_Elev (ft)	Z from LiDAR Bare Earth TIN (ft)	Delta Z (ft)	Absolute Difference (cm)	Exceed Blunder Criteria(Y/N)
1001	Brush, Low Trees	202861.924000	292717.482000	663.445000	664.113000	-0.668000	20.36	N
1002	Forested	231061.768000	292170.246000	722.901000	723.090000	-0.189000	5.76	N
1003	High Grass, Weeds, Crops	260314.480000	289290.011000	814.495000	815.214000	-0.719000	21.92	N
1004	Urban	279870.980000	243726.731000	989.592000	989.569000	0.023000	0.70	N
1005	Low Grass, Bare Earth	259941.054000	273509.170000	947.465000	947.568000	-0.103000	3.14	N
1006	Brush, Low Trees	261876.410000	281658.490000	874.953000	875.298000	-0.345000	10.52	N
1007	Forested	253776.192000	263100.797000	1209.295000	1209.687000	-0.392000	11.95	N
1008	Urban	246367.220000	257539.979000	1193.111000	1193.288000	-0.177000	5.39	N
1009	Low Grass, Bare Earth	234967.921000	262283.459000	928.747000	928.888000	-0.141000	4.30	N
1010	High Grass, Weeds, Crops	201119.220000	266094.532000	823.982000	825.224000	-1.242000	37.86	Y

Douglas County Survey Checkpoints (Douglas County Coordinate System (FT))					LiDAR Elevations	Results		
1011	Low Grass, Bare Earth	207678.512000	283228.244000	707.422000	707.429000	- 0.007000	0.21	N
1012	High Grass, Weeds, Crops	172361.086000	283431.377000	672.133000	672.751000	- 0.618000	18.84	N
1013	Urban	173644.436000	278701.910000	691.531000	691.617000	- 0.086000	2.62	N
1014	Low Grass, Bare Earth	170606.466000	261517.030000	758.011000	758.238000	- 0.227000	6.92	N
1015	Forested	142091.513000	263665.628000	688.902000	688.926000	- 0.024000	0.73	N
1016	Urban	146626.857000	278059.089000	677.650000	677.465000	0.185000	5.64	N
1017	Low Grass, Bare Earth	136632.681000	279336.162000	685.846000	686.386000	- 0.540000	16.46	N
1019	High Grass, Weeds, Crops	124910.656000	272044.330000	739.303000	739.481000	- 0.178000	5.43	N
1020	Low Grass, Bare Earth	110967.860000	262380.430000	813.976000	814.127000	- 0.151000	4.60	N
1021	Brush, Low Trees	111522.252000	250148.791000	815.276000	816.105000	- 0.829000	25.27	N
1022	Low Grass, Bare Earth	106010.146000	231645.038000	875.114000	875.514000	- 0.400000	12.19	N
1023	Forested	141934.910000	237807.612000	978.377000	978.952000	- 0.575000	17.53	N
1024	Low Grass, Bare Earth	142104.840000	255400.748000	709.435000	709.502000	- 0.067000	2.04	N
1025	Brush, Low Trees	169301.399000	230760.621000	1144.095000	1144.341000	- 0.246000	7.50	N
1026	High Grass, Weeds, Crops	177730.433000	248515.981000	991.667000	991.874000	- 0.207000	6.31	N
1027	Low Grass, Bare Earth	200855.600000	246672.226000	1091.446000	1091.807000	- 0.361000	11.00	N
1028	Urban	204377.305000	239985.721000	1124.729000	1124.736000	- 0.007000	0.21	N
1029	Urban	223876.941000	255669.743000	977.133000	977.178000	- 0.045000	1.37	N
1030	Forested	220505.749000	247024.796000	1092.746000	1093.105000	- 0.359000	10.94	N
1031	Brush, Low Trees	241711.378000	247034.292000	1160.030000	1160.918000	- 0.888000	27.07	N
1032	Low Grass, Bare Earth	229845.553000	226417.687000	1177.044000	1177.270000	- 0.226000	6.89	N
1033	Urban	247903.750000	230445.483000	1145.011000	1145.102000	- 0.091000	2.77	N



Douglas County Survey Checkpoints (Douglas County Coordinate System (FT))					LiDAR Elevations	Results		
1034	High Grass, Weeds, Crops	269149.753000	236025.906000	1060.371000	1060.727000	- 0.356000	10.85	N
1035	Low Grass, Bare Earth	280103.435000	234153.494000	1080.658000	1081.135000	- 0.477000	14.54	N
1036	Forested	275606.363000	204067.988000	1229.058000	1229.441000	- 0.383000	11.67	N
1037	Urban	265711.519000	215840.069000	1221.929000	1222.189000	- 0.260000	7.92	N
1038	Low Grass, Bare Earth	255011.709000	207981.224000	1219.815000	1220.244000	- 0.429000	13.08	N
1039	High Grass, Weeds, Crops	241993.536000	202693.236000	1177.227000	1177.629000	- 0.402000	12.25	N
1040	Low Grass, Bare Earth	228902.177000	205017.348000	1221.233000	1221.632000	- 0.399000	12.16	N
1041	Brush, Low Trees	209560.178000	215582.596000	1162.078000	1163.069000	- 0.991000	30.21	Y
1042	Low Grass, Bare Earth	197274.269000	202960.706000	1196.342000	1196.487000	- 0.145000	4.42	N
1043	Forested	175659.461000	202409.248000	1230.016000	1229.849000	- 0.167000	5.09	N
1044	Low Grass, Bare Earth	163012.715000	216322.806000	1199.853000	1199.876000	- 0.023000	0.70	N
1045	Brush, Low Trees	148753.950000	195123.896000	1234.765000	1235.064000	- 0.299000	9.11	N
1046	Low Grass, Bare Earth	132091.676000	216035.637000	1221.031000	1221.038000	- 0.007000	0.21	N
1047	High Grass, Weeds, Crops	102485.846000	201409.855000	1299.303000	1299.523000	- 0.220000	6.71	N
1048	Low Grass, Bare Earth	101060.650000	215872.870000	1044.319000	1044.502000	- 0.183000	5.58	N
1049	Urban	116984.588000	221670.020000	1003.882000	1003.864000	- 0.018000	0.55	N
1050	Forested	143786.904000	177393.623000	1310.993000	1310.901000	- 0.092000	2.80	N
1051	Low Grass, Bare Earth	158978.304000	189630.045000	1269.821000	1270.113000	- 0.292000	8.90	N
1052	High Grass, Weeds, Crops	169945.447000	179026.404000	1274.293000	1276.273000	- 1.980000	60.35	Y
1053	Low Grass, Bare Earth	188324.396000	171686.368000	1222.858000	1222.942000	- 0.084000	2.56	N
1054	Brush, Low Trees	197193.470000	178790.280000	1262.310000	1262.459000	- 0.149000	4.54	N
1055	Urban	214385.429000	171079.038000	1139.533000	1139.611000	- 0.078000	2.38	N
1056	Low Grass, Bare Earth	215399.730000	190941.861000	1241.001000	1241.167000	- 0.166000	5.06	N



Douglas County Survey Checkpoints (Douglas County Coordinate System (FT))					LiDAR Elevations	Results		
1057	Forested	234962.988000	191047.607000	1068.361000	1068.476000	- 0.115000	3.51	N
1058	Low Grass, Bare Earth	247457.511000	173997.002000	1154.878000	1155.209000	- 0.331000	10.09	N
1059	Brush, Low Trees	258845.640000	189663.301000	1198.746000	1198.809000	- 0.063000	1.92	N
1060	Low Grass, Bare Earth	280619.365000	188726.590000	1201.458000	1201.345000	0.113000	3.44	N
1061	Urban	282311.702000	173992.076000	1182.264000	1182.312000	- 0.048000	1.46	N
1062	Low Grass, Bare Earth	275827.295000	147602.408000	1177.380000	1177.557000	- 0.177000	5.39	N
1063	High Grass, Weeds, Crops	265286.315000	154626.975000	1139.201000	1139.701000	- 0.500000	15.24	N
1064	Forested	280300.388000	129170.579000	1158.586000	1158.794000	- 0.208000	6.34	N
1065	Brush, Low Trees	274689.593000	118045.340000	1144.328000	1145.030000	- 0.702000	21.40	N
1066	Low Grass, Bare Earth	259977.467000	118469.727000	1134.280000	1134.443000	- 0.163000	4.97	N
1067	Urban	249266.086000	123678.558000	1118.878000	1118.854000	0.024000	0.73	N
1068	High Grass, Weeds, Crops	238243.941000	123897.220000	1067.439000	1067.975000	- 0.536000	16.34	N
1069	Low Grass, Bare Earth	231677.201000	113021.078000	1107.029000	1106.985000	0.044000	1.34	N
1070	Low Grass, Bare Earth	239464.263000	136997.540000	1118.442000	1118.418000	0.024000	0.73	N
1071	Forested	250014.214000	155589.575000	1145.863000	1146.066000	- 0.203000	6.19	N
1072	Urban	230233.109000	141834.722000	1035.152000	1035.129000	0.023000	0.70	N
1073	Urban	224177.059000	132009.691000	1036.020000	1035.864000	0.156000	4.75	N
1074	Low Grass, Bare Earth	116128.747000	122008.570000	1143.818000	1143.569000	0.249000	7.59	N
1075	High Grass, Weeds, Crops	105637.118000	121101.594000	1133.356000	1133.592000	- 0.236000	7.19	N
1076	Forested	112860.754000	131859.583000	1168.613000	1168.509000	0.104000	3.17	N
1077	Brush, Low Trees	126074.035000	111240.368000	1100.028000	1100.377000	- 0.349000	10.64	N
1078	Urban	133600.341000	121516.600000	1122.118000	1121.737000	0.381000	11.61	N
1079	Low Grass, Bare Earth	127083.653000	133098.815000	1157.869000	1157.572000	0.297000	9.05	N
1080	Brush, Low Trees	116846.644000	147695.300000	1204.798000	1205.299000	- 0.501000	15.27	N
1081	Urban	133921.028000	152625.967000	1245.349000	1245.318000	0.031000	0.94	N
1082	Brush, Low Trees	137315.520000	169857.915000	1292.807000	1292.644000	0.163000	4.97	N
1083	Low Grass, Bare Earth	119098.406000	178566.458000	1298.601000	1298.198000	0.403000	12.28	N
1084	High Grass, Weeds, Crops	147351.496000	151003.355000	1247.404000	1247.878000	- 0.474000	14.45	N

Douglas County Survey Checkpoints (Douglas County Coordinate System (FT))					LiDAR Elevations	Results		
1085	Forested	157083.599000	147076.701000	1225.643000	1225.898000	- 0.255000	7.77	N
1086	Brush, Low Trees	108857.429000	189322.783000	1273.547000	1274.119000	- 0.572000	17.43	N
1087	Brush, Low Trees	119958.988000	195345.315000	1273.962000	1274.096000	- 0.134000	4.08	N
1088	Urban	189002.226000	152027.675000	1131.741000	1132.170000	- 0.429000	13.08	N
1089	Brush, Low Trees	173480.943000	136755.997000	1111.958000	1112.419000	- 0.461000	14.05	N
1091	High Grass, Weeds, Crops	165247.511000	110499.074000	1062.203000	1063.195000	- 0.992000	30.24	Y
1092	Low Grass, Bare Earth	154862.709000	126440.062000	1111.051000	1111.633000	- 0.582000	17.74	N
1093	Urban	186796.020000	125909.814000	1083.747000	1083.670000	0.077000	2.35	N
1094	Urban	197628.771000	105507.413000	1033.054000	1033.032000	0.022000	0.67	N
1095	Brush, Low Trees	214467.681000	126605.583000	1095.990000	1096.152000	- 0.162000	4.94	N
1096	High Grass, Weeds, Crops	212550.232000	152157.874000	1087.015000	1087.418000	- 0.403000	12.28	N
1097	Low Grass, Bare Earth	271188.258000	315456.127000	628.610000	628.653000	- 0.043000	1.31	N
1098	Forested	282405.486000	257764.887000	1060.136000	1060.890000	- 0.754000	22.98	N
1099	Low Grass, Bare Earth	192814.201000	217567.107000	1252.749000	1252.896000	- 0.147000	4.48	N
1100	Brush, Low Trees	227192.445000	166337.169000	1103.130000	1103.080000	0.050000	1.52	N
1101	Brush, Low Trees	258063.183000	137012.228000	1131.432000	1131.889000	- 0.457000	13.93	N

4.2 APPENDIX B: FLASH DRIVE CONTAINING AN ESRI SHAPEFILE OF CHECKPOINTS AND PHOTOS

4.3 APPENDIX C: SURVEY REPORT OF CHECKPOINTS

4.3.1 INTRODUCTION

Houston Engineering, Inc. (HEI) utilized a number of the latest technologies available in surveying to make the measurements needed to determine the quality of the LiDAR data recently provided to Douglas County. This LiDAR QC Checkpoint Survey was carefully designed to utilize existing State of Wisconsin and Douglas County resources to obtain an efficient and accurate verification of the LiDAR data.

4.3.2 LIDAR QC CHECKPOINT SURVEY PARAMETERS

To match the LiDAR project deliverables, the QC Checkpoint Survey data is delivered with the following parameters:

Horizontal Datum: North American Datum of 1983(2011) Wisconsin Coordinate Reference System (WISCRS) Douglas County Coordinates

Vertical Datum: North American Vertical Datum of 1988 (Geoid12A)

Survey Units: US Survey Feet

4.3.3 PROCEDURES AND METHODS

Houston Engineering, Inc. (HEI) used several different measurement technologies and systems to obtain the required QC Checkpoint Survey measurements. Survey grade GPS equipment was used as the primary measurement system. Real-time measurement methods were used on all GPS based measurements. An optical robotic survey instrument was used for measurements where conditions didn't allow GPS based measurements. The primary basis for survey control on the project was the Wisconsin Continuously Operating Reference Station Network (WISCORS). The WISCORS network is operated by the Wisconsin Department of Transportation, and is in-place across the state of Wisconsin to provide the corrections needed to achieve survey grade, highly accurate measurements with GPS equipment. The WISCORS system uses a network of continuously operating base or reference stations that are all connected online via the web to a central computer system. The QC Checkpoint Survey accessed this central computer system which assigned one of the specific WISCORS reference stations to provide the basis or corrections for that specific particular measurement. **Appendix D (contained on the thumb drive)** contains a map of the Continuously Operating Reference Stations (CORS) in-place across Wisconsin. For this QC Checkpoint Survey five nearby CORS were utilized as follows:

WISCORS Stations
utilized for
QC Checkpoint Survey

Cable
Dairyland

Iron River
Minong
Superior

Data sheets for each WISCORS station utilized are included in **Appendix D (on the thumb drive)**.

In addition to the WISCORS system, Douglas County has a number of geodetic control monuments established across the county. Twenty-two of these geodetic control monuments were utilized in the QC Checkpoint Survey. These control monuments were used as base points for GPS measurements, as base points for the optical measurements, or as checkpoints for measurements made from the WISCORS system. The following Douglas County control monuments were used in this QC Checkpoint Survey:

Douglas County
Geodetic Control Monuments
used for
QC Checkpoint Survey Control

400	421	432
402	424	438
404	426	441
408	427	443
409	428	446
410	430	447
411	431	504
420		

Data sheets for each Douglas County Geodetic Control monument referenced in this survey are attached in **Appendix C**. One National Geodetic Survey (NGS) control monument was checked into for a check of the elevation data. The data sheet for NGS control monument 8B57 is attached in **Appendix D**.

GPS measurements were made with a Trimble R8 Model 4 GNSS Receiver, utilizing both GPS and GLONASS satellites. For optical measurements, a Trimble S6 Robotic Total Station was used. A Trimble TSC3 data collector was utilized to electronically collect the survey measurements and operate the GPS and optical instruments, and to connect with the WISCORS central computer. A Verizon Wireless cellular mobile hot-spot was used to connect to the web to provide the link for the data collector to access the WISCORS central computer. In QC checkpoint locations where cellular coverage was unavailable, a HEI GPS base station was set-up on a nearby Douglas County Geodetic Control Monument for establishing corrections, and the corrections were broadcast to the main GPS rover unit via a radio link. A Trimble R8 Model 3 GNSS Receiver was utilized for the base station, with a Trimble TDL450H radio used to broadcast the corrections.

Checkpoint measurements that are situated in a Land Class 5 (Forested Area) location can be difficult to acquire with GPS equipment, as the tree canopy blocks or distorts the signals received from the satellites. To overcome this problem where needed, GPS was used to set temporary reference points (RPs) in an area open to the sky for good GPS measurements, but near enough to the tree covered checkpoint site to allow for the optical survey measurement from the RP to the checkpoint. An optical total station was then set up on one of the RPs, with a backsight taken on the other RP, and used to measure the position of the obstructed checkpoint.

To verify the accuracy of the survey methods used, cross-check measurements were made using GPS equipment running based on the WISCORS system into a number of the Douglas County Geodetic

Control and NGS monuments, or between various Douglas County Geodetic Control monuments, to see if the results were within acceptable tolerances. **Table 4** lists the results of the cross-checking measurements made between monuments. All QC Checkpoint Survey measurements were collected on April 17 – 21 and 25 – 27, 2017.

4.3.4 FINAL RESULTS – QC CHECKPOINT SURVEY:

A listing of the final results for position and elevation for each of the 99 QC checkpoints surveyed is included in the attached **Table 2**. This table included the WISCRS northing and easting coordinates and the NAVD 88 elevations, as well as the latitude, longitude, and ellipsoid height for the each of the QC checkpoints. Also included in **Table 2** are the survey positions determined for the various reference points set and control monuments checked into. Quality data for all of the GPS measurements is included in **Table 3** including base point, observation start date/time and duration, PDOP, HDOP, VDOP and RMS statistics, and number of satellites observed. **Table 4** lists the observation details and quality information for the optical measurements. **Table 5** lists the results of the check shots into Douglas County Geodetic Control and NGS and monuments.

Table 2: QC Checkpoint Results

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
101	287995.32	179687.22	649.96	CHK 446	46.67299462	-91.97367719	557.19
102	291961.24	231009.32	723.72	RP NAIL	46.68378751	-91.76922216	629.79
103	292061.35	231017.97	724.99	RP NAIL	46.68406194	-91.76918695	631.12
104	254259.16	256236.54	1135.92	CHK 443	46.58024315	-91.66918971	1042.85
105	263082.57	253851.40	1210.73	RP NAIL	46.60445530	-91.67856798	1117.30
106	263082.69	253952.45	1208.59	RP NAIL	46.60445479	-91.67816599	1115.11
107	287339.51	172656.41	648.50	CHK 447	46.67117914	-92.00167939	555.83
108	278805.88	223554.41	790.32	CHK 432	46.64775282	-91.79900061	697.11
109	283708.75	132177.58	667.09	CHK 431	46.66099111	-92.16286266	574.62
110	237795.37	142072.25	983.56	RP NAIL	46.53518371	-92.12298095	892.87
111	237848.44	142112.47	983.89	RP NAIL	46.53532951	-92.12282171	893.13
112	258000.46	198650.80	950.34	CHK 438	46.59076733	-91.89816970	858.76
113	258000.51	198650.81	950.31	CHK 438	46.59076745	-91.89816965	858.74
114	255274.74	227296.29	987.01	CHK 504	46.58321874	-91.78426028	895.04
115	247060.45	220615.59	1094.05	RP NAIL	46.56072425	-91.81087061	1002.76
116	246932.67	220659.88	1095.10	RP NAIL	46.56037374	-91.81069522	1003.84

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
117	204070.87	275535.39	1227.70	RP NAIL	46.44244429	-91.59326822	1135.53
118	204172.78	275509.12	1226.21	RP NAIL	46.44272401	-91.59337077	1134.09
119	215759.82	253934.77	1137.47	CHK 441	46.47470396	-91.67880359	1046.05
120	202458.12	175719.84	1229.20	RP NAIL	46.43845656	-91.98916701	1140.58
121	202393.19	175777.23	1227.25	RP NAIL	46.43827866	-91.98893913	1138.58
122	242303.57	142914.28	851.88	CHK 430	46.54755042	-92.11968160	760.93
123	200395.36	107586.19	1277.06	CHK 410	46.43231025	-92.25935112	1187.60
124	177358.00	143838.29	1307.54	RP NAIL	46.36948456	-92.11536078	1219.75
125	177442.21	143887.58	1306.25	RP NAIL	46.36971579	-92.11516639	1218.50
126	171173.41	212965.73	1140.16	CHK 427	46.35267479	-91.84156508	1051.55
127	191057.07	234913.06	1068.88	RP NAIL	46.40710397	-91.75449576	979.05
128	190960.46	234941.29	1068.20	RP NAIL	46.40683889	-91.75438462	978.39
129	174043.26	254920.98	1174.49	CHK 408	46.36031386	-91.67539468	1084.17
130	131940.21	281237.15	1154.06	CHK 402	46.24460361	-91.57189894	1063.44
131	129099.13	280274.69	1156.01	RP NAIL	46.23682495	-91.57575082	1065.44
132	129018.29	280199.72	1152.82	RP NAIL	46.23660417	-91.57604842	1062.23
133	155519.31	249965.29	1145.75	RP NAIL	46.30956230	-91.69522618	1055.94
134	155441.22	249962.04	1146.53	RP NAIL	46.30934820	-91.69523989	1056.84
135	147670.83	217405.17	1088.27	CHK 421	46.28821901	-91.82409432	999.65
136	147661.02	149707.76	1222.69	RP NAIL	46.28809537	-92.09185136	1135.61
137	147789.73	144966.62	1235.42	CHK WDOT 8B57	46.28841801	-92.11060467	1148.37
138	147364.83	174433.82	1162.46	RP NAIL	46.28739124	-91.99405385	1075.06
139	147606.61	198970.17	1070.79	RP NAIL	46.28807870	-91.89700865	982.76
140	117510.18	186917.78	1056.72	CHK 424	46.20555291	-91.94463628	968.94
141	147606.60	198970.22	1070.70	CHK 139	46.28807868	-91.89700846	982.67
142	147670.84	217405.20	1088.18	CHK 421	46.28821902	-91.82409418	999.57
143	226201.02	222033.04	1168.24	CHK 411	46.50352555	-91.80535319	1077.87
144	137043.19	260237.41	1133.28	CHK 404	46.25881590	-91.65482388	1043.33

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
1001	292717.48	202861.92	663.45	CL 4	46.68595050	-91.88135950	570.25
1002	292170.25	231061.77	722.90	CL 5	46.68436028	-91.76901163	629.03
1003	289290.01	260314.48	814.50	CL 3	46.67625366	-91.65250755	719.50
1004	243726.73	279870.98	989.59	CL 2	46.55112359	-91.57539249	895.57
1005	273509.17	259941.05	947.47	CL 1	46.63298976	-91.65420446	853.15
1006	281658.49	261876.41	874.95	CL 4	46.65531536	-91.64639008	780.16
1007	263100.80	253776.19	1209.30	CL 5	46.60450589	-91.67886692	1115.87
1008	257539.98	246367.22	1193.11	CL 2	46.58931669	-91.70839927	1100.33
1009	262283.46	234967.92	928.75	CL 1	46.60239596	-91.75369573	836.09
1010	266094.53	201119.22	823.98	CL 3	46.61295778	-91.88834081	731.88
1011	283228.24	207678.51	707.42	CL 1	46.65992555	-91.86219568	614.40
1012	283431.38	172361.09	672.13	CL 3	46.66046301	-92.00283866	579.55
1013	278701.91	173644.44	691.53	CL 2	46.64749954	-91.99770865	599.08
1014	261517.03	170606.47	758.01	CL 1	46.60037278	-92.00972299	666.29
1015	263665.63	142091.51	688.90	CL 5	46.60611531	-92.12317346	596.93
1016	278059.09	146626.86	677.65	CL 2	46.64561032	-92.10526768	585.31
1017	279336.16	136632.68	685.85	CL 1	46.64903926	-92.14507074	593.46
1018	282045.86	123694.07	651.82	CL 2	46.65635417	-92.19662271	559.31
1019	272044.33	124910.66	739.30	CL 3	46.62894407	-92.19163938	646.97
1020	262380.43	110967.86	813.98	CL 1	46.60230110	-92.24696913	721.71
1021	250148.79	111522.25	815.28	CL 4	46.56877098	-92.24456152	723.31
1022	231645.04	106010.15	875.11	CL 1	46.51797258	-92.26614909	783.73
1023	237807.61	141934.91	978.38	CL 5	46.53521630	-92.12352675	887.68
1024	255400.75	142104.84	709.44	CL 1	46.58345473	-92.12303441	617.78
1025	230760.62	169301.40	1144.10	CL 4	46.51603945	-92.01476228	1054.19
1026	248515.98	177730.43	991.67	CL 3	46.56474572	-91.98134243	900.74
1027	246672.23	200855.60	1091.45	CL 1	46.55970548	-91.88941640	1000.54
1028	239985.72	204377.31	1124.73	CL 2	46.54136795	-91.87543189	1034.15

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
1029	255669.74	223876.94	977.13	CL 2	46.58431671	-91.79785532	885.24
1030	247024.80	220505.75	1092.75	CL 5	46.56062690	-91.81130739	1001.46
1031	247034.29	241711.38	1160.03	CL 4	46.56054425	-91.72701615	1068.01
1032	226417.69	229845.55	1177.04	CL 1	46.50408523	-91.77432984	1086.38
1033	230445.48	247903.75	1145.01	CL 2	46.51501711	-91.70258076	1053.39
1034	236025.91	269149.75	1060.37	CL 3	46.53012857	-91.61811663	967.33
1035	234153.49	280103.44	1080.66	CL 1	46.52487293	-91.57463352	987.01
1036	204067.99	275606.36	1229.06	CL 5	46.44243559	-91.59298678	1136.88
1037	215840.07	265711.52	1221.93	CL 2	46.47481724	-91.63206460	1129.86
1038	207981.22	255011.71	1219.82	CL 1	46.45336717	-91.67462412	1128.59
1039	202693.24	241993.54	1177.23	CL 3	46.43896579	-91.72631933	1086.81
1040	205017.35	228902.18	1221.23	CL 1	46.44541287	-91.77822470	1131.33
1041	215582.60	209560.18	1162.08	CL 4	46.47444869	-91.85491330	1072.47
1042	202960.71	197274.27	1196.34	CL 1	46.43985683	-91.90368037	1107.46
1043	202409.25	175659.46	1230.02	CL 5	46.43832239	-91.98940628	1141.40
1044	216322.81	163012.72	1199.85	CL 1	46.47642881	-92.03964976	1110.66
1045	195123.90	148753.95	1234.77	CL 4	46.41822913	-92.09604915	1146.37
1046	216035.64	132091.68	1221.03	CL 1	46.47544365	-92.16236552	1131.39
1047	201409.86	102485.85	1299.30	CL 3	46.43502945	-92.27959523	1209.60
1048	215872.87	101060.65	1044.32	CL 1	46.47466652	-92.28551482	953.65
1049	221670.02	116984.59	1003.88	CL 2	46.49074769	-92.22240757	913.40
1050	177393.62	143786.90	1310.99	CL 5	46.36958189	-92.11556469	1223.20
1051	189630.05	158978.30	1269.82	CL 1	46.40322193	-92.05547559	1181.68
1052	179026.40	169945.45	1274.29	CL 3	46.37419213	-92.01195665	1186.46
1053	171686.37	188324.40	1222.86	CL 1	46.35410374	-91.93914183	1134.94
1054	178790.28	197193.47	1262.31	CL 4	46.37358369	-91.90401616	1174.08
1055	171079.04	214385.43	1139.53	CL 2	46.35241220	-91.83594368	1050.86
1056	190941.86	215399.73	1241.00	CL 1	46.40687159	-91.83184292	1151.98

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
1057	191047.61	234962.99	1068.36	CL 5	46.40707773	-91.75429791	978.53
1058	173997.00	247457.51	1154.88	CL 1	46.36024558	-91.70495333	1064.87
1059	189663.30	258845.64	1198.75	CL 4	46.40310854	-91.65965067	1107.89
1060	188726.59	280619.37	1201.46	CL 1	46.40031370	-91.57336790	1109.58
1061	173992.08	282311.70	1182.26	CL 2	46.35989320	-91.56691884	1090.80
1062	147602.41	275827.30	1177.38	CL 1	46.28761083	-91.59302609	1086.78
1063	154626.98	265286.32	1139.20	CL 3	46.30698211	-91.63461800	1048.86
1064	129170.58	280300.39	1158.59	CL 5	46.23702056	-91.57564807	1068.02
1065	118045.34	274689.59	1144.33	CL 4	46.20657960	-91.59799547	1053.96
1066	118469.73	259977.47	1134.28	CL 1	46.20789045	-91.65609258	1044.40
1067	123678.56	249266.09	1118.88	CL 2	46.22226158	-91.69833961	1029.36
1068	123897.22	238243.94	1067.44	CL 3	46.22293600	-91.74188014	978.26
1069	113021.08	231677.20	1107.03	CL 1	46.19315036	-91.76790260	1018.00
1070	136997.54	239464.26	1118.44	CL 1	46.25884932	-91.73694201	1029.18
1071	155589.58	250014.21	1145.86	CL 5	46.30975459	-91.69503182	1056.04
1072	141834.72	230233.11	1035.15	CL 2	46.27216427	-91.77339898	946.15
1073	132009.69	224177.06	1036.02	CL 2	46.24525176	-91.79740329	947.24
1074	122008.57	116128.75	1143.82	CL 1	46.21747712	-92.22426809	1057.14
1075	121101.59	105637.12	1133.36	CL 3	46.21487122	-92.26569487	1046.64
1076	131859.58	112860.75	1168.61	CL 5	46.24445268	-92.23733414	1081.77
1077	111240.37	126074.04	1100.03	CL 4	46.18804988	-92.18483970	1013.41
1078	121516.60	133600.34	1122.12	CL 2	46.21629301	-92.15524791	1035.41
1079	133098.82	127083.65	1157.87	CL 1	46.24799444	-92.18114134	1071.06
1080	147695.30	116846.64	1204.80	CL 4	46.28791636	-92.22182273	1117.64
1081	152625.97	133921.03	1245.35	CL 2	46.30159626	-92.15434948	1158.20
1082	169857.92	137315.52	1292.81	CL 4	46.34887217	-92.14111354	1205.21
1083	178566.46	119098.41	1298.60	CL 1	46.37258577	-92.21337407	1210.49
1084	151003.36	147351.50	1247.40	CL 3	46.29724524	-92.10120160	1160.28

Point ID	Northing (US Feet)	Easting (US Feet)	Elevation (US Feet)	Feature Code	Latitude	Longitude	Ellipsoid Height (US Feet)
1085	147076.70	157083.60	1225.64	CL 5	46.28653417	-92.06267429	1138.51
1086	189322.78	108857.43	1273.55	CL 4	46.40196580	-92.25412264	1184.71
1087	195345.32	119958.99	1273.96	CL 4	46.41860019	-92.21021168	1185.11
1088	152027.68	189002.23	1131.74	CL 2	46.30020109	-91.93643822	1043.99
1089	136756.00	173480.94	1111.96	CL 4	46.25829950	-91.99777968	1024.60
1090	110742.60	144283.09	1069.77	CL 5	46.18683104	-92.11294564	982.93
1091	110499.07	165247.51	1062.20	CL 3	46.18627542	-92.03017839	974.92
1092	126440.06	154862.71	1111.05	CL 1	46.22993751	-92.07129894	1024.08
1093	125909.81	186796.02	1083.75	CL 2	46.22858460	-91.94512904	996.02
1094	105507.41	197628.77	1033.05	CL 2	46.17264364	-91.90234421	944.85
1095	126605.58	214467.68	1095.99	CL 4	46.23046734	-91.83579765	1007.49
1096	152157.87	212550.23	1087.02	CL 3	46.30053625	-91.84328016	998.55
1097	315456.13	271188.26	628.61	CL 1	46.74788576	-91.60878551	532.46
1098	257764.89	282405.49	1060.14	CL 5	46.58958264	-91.56507125	965.39
1099	217567.11	192814.20	1252.75	CL 1	46.47990655	-91.92137320	1163.39
1100	166337.17	227192.45	1103.13	CL 4	46.33936326	-91.78526124	1014.03
1101	137012.23	258063.18	1131.43	CL 4	46.25875038	-91.66341910	1041.56

Table 3: Quality Data of GPS Measurements

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
101	287995.32	179687.22	649.96	CHK 446	GNSS	Superior	101	4/17/2017 9:05	00:30.0	1.591	0.848	1.346	0.015	15
102	291961.24	231009.32	723.72	RP NAIL	GNSS	Superior	102	4/17/2017 10:30	03:49.0	2.371	1.061	2.120	0.011	12
103	292061.35	231017.97	724.99	RP NAIL	GNSS	Superior	103	4/17/2017 10:35	03:00.0	2.368	1.061	2.117	0.013	12
104	254259.16	256236.54	1135.92	CHK 443	GNSS	Iron River	104	4/17/2017 13:12	00:31.0	1.524	0.675	1.367	0.013	15
105	263082.57	253851.40	1210.73	RP NAIL	GNSS	Iron River	105	4/17/2017 15:05	03:00.0	2.245	0.996	2.012	0.020	12
106	263082.69	253952.45	1208.59	RP NAIL	GNSS	Iron River	106	4/17/2017 15:10	03:19.0	1.798	0.861	1.579	0.011	13
107	287339.51	172656.41	648.50	CHK 447	GNSS	Superior	107	4/17/2017 17:22	00:32.0	1.317	0.693	1.120	0.011	15
108	278805.88	223554.41	790.32	CHK 432	GNSS	Superior	108	4/18/2017 8:46	00:29.0	1.222	0.746	0.967	0.019	15
109	283708.75	132177.58	667.09	CHK 431	GNSS	Superior	109	4/18/2017 11:58	00:37.0	1.822	1.004	1.521	0.022	12
110	237795.37	142072.25	983.56	RP NAIL	GNSS	Superior	110	4/18/2017 14:12	03:00.0	1.741	0.882	1.501	0.018	13
111	237848.44	142112.47	983.89	RP NAIL	GNSS	Superior	111	4/18/2017 14:16	03:00.0	1.481	0.715	1.297	0.017	14
112	258000.46	198650.80	950.34	CHK 438	GNSS	Superior	112	4/18/2017 17:19	00:31.0	1.294	0.730	1.068	0.013	15
113	258000.51	198650.81	950.31	CHK 438	GNSS	Superior	113	4/19/2017 7:41	00:31.0	1.285	0.697	1.080	0.010	18
114	255274.74	227296.29	987.01	CHK 504	GNSS	Superior	114	4/19/2017 7:59	00:30.0	1.149	0.657	0.942	0.014	18
115	247060.45	220615.59	1094.05	RP NAIL	GNSS	Superior	115	4/19/2017 8:40	03:00.0	1.409	0.766	1.182	0.018	14
116	246932.67	220659.88	1095.10	RP NAIL	GNSS	Superior	116	4/19/2017 8:44	03:00.0	1.441	0.848	1.167	0.017	14
117	204070.87	275535.39	1227.70	RP NAIL	GNSS	Iron River	117	4/19/2017 11:46	03:00.0	1.456	0.857	1.177	0.014	13

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
118	204172.78	275509.12	1226.21	RP NAIL	GNSS	Iron River	118	4/19/2017 11:51	03:00.0	1.489	0.897	1.188	0.011	13
119	215759.82	253934.77	1137.47	CHK 441	GNSS	Iron River	119	4/19/2017 12:38	00:34.0	1.725	0.836	1.509	0.018	12
120	202458.12	175719.84	1229.20	RP NAIL	GNSS	Superior	120	4/19/2017 15:08	03:00.0	2.902	1.019	2.717	0.022	10
121	202393.19	175777.23	1227.25	RP NAIL	GNSS	Superior	121	4/19/2017 15:12	03:00.0	2.087	0.903	1.881	0.016	11
122	242303.57	142914.28	851.88	CHK 430	GNSS	Superior	122	4/19/2017 17:26	00:34.0	1.284	0.719	1.064	0.011	15
123	200395.36	107586.19	1277.06	CHK 410	GNSS	Dairyland	123	4/20/2017 8:59	00:31.0	1.708	0.911	1.445	0.018	13
124	177358.00	143838.29	1307.54	RP NAIL	GNSS	Dairyland	124	4/20/2017 11:07	03:00.0	1.570	0.842	1.325	0.021	15
125	177442.21	143887.58	1306.25	RP NAIL	GNSS	Dairyland	125	4/20/2017 11:12	03:00.0	1.658	0.951	1.358	0.014	14
126	171173.41	212965.73	1140.16	CHK 427	GNSS	Minong	126	4/20/2017 14:14	00:31.0	1.351	0.700	1.155	0.016	15
127	191057.07	234913.06	1068.88	RP NAIL	GNSS	Minong	127	4/20/2017 14:37	03:00.0	1.676	0.861	1.441	0.016	16
128	190960.46	234941.29	1068.20	RP NAIL	GNSS	Minong	128	4/20/2017 14:40	03:00.0	1.997	1.117	1.656	0.016	15
129	174043.26	254920.98	1174.49	CHK 408	GNSS	Minong	129	4/20/2017 17:34	00:36.0	1.484	0.793	1.254	0.012	14
130	131940.21	281237.15	1154.06	CHK 402	GNSS	Cable	130	4/21/2017 8:39	00:31.0	2.185	1.166	1.848	0.011	12
131	129099.13	280274.69	1156.01	RP NAIL	GNSS	Cable	131	4/21/2017 8:53	03:00.0	1.825	0.970	1.545	0.022	14
132	129018.29	280199.72	1152.82	RP NAIL	GNSS	Cable	132	4/21/2017 8:58	03:00.0	2.281	1.354	1.837	0.016	10
133	155519.31	249965.29	1145.75	RP NAIL	GNSS	Minong	133	4/21/2017 11:56	03:00.0	1.903	1.057	1.599	0.016	10
134	155441.22	249962.04	1146.53	RP NAIL	GNSS	Minong	134	4/21/2017 12:01	03:00.0	2.060	1.276	1.625	0.015	10
135	147670.83	217405.17	1088.27	CHK 421	GNSS	Minong	135	4/21/2017 13:03	00:30.0	1.724	0.726	1.564	0.012	15

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
136	147661.02	149707.76	1222.69	RP NAIL	GNSS	CHK 404	136	4/25/2017 12:23	03:00.0	1.834	0.812	1.644	0.013	15
137	147789.73	144966.62	1235.42	WDOT 8B57	GNSS	136	137	4/25/2017 15:29	00:41.0	1.990	1.073	1.676	0.019	12
138	147364.83	174433.82	1162.46	RP NAIL	GNSS	136	138	4/25/2017 16:22	03:00.0	2.540	1.180	2.253	0.009	10
139	147606.61	198970.17	1070.79	RP NAIL	GNSS	138	139	4/26/2017 10:43	03:00.0	1.423	0.745	1.212	0.013	14
140	117510.18	186917.78	1056.72	CHK 424	GNSS	Minong	140	4/26/2017 14:06	00:33.0	1.801	0.883	1.570	0.009	13
141	147606.60	198970.22	1070.70	CHK 139	GNSS	Minong	141	4/26/2017 15:54	03:00.0	1.505	0.876	1.223	0.012	14
142	147670.84	217405.20	1088.18	CHK 421	GNSS	Minong	142	4/26/2017 16:22	00:31.0	1.722	0.898	1.470	0.012	12
143	226201.02	222033.04	1168.24	CHK 411	GNSS	Superior	143	4/27/2017 10:34	00:32.0	1.615	0.840	1.380	0.022	14
144	137043.19	260237.41	1133.28	CHK 404	GNSS	Minong	144	4/27/2017 12:45	00:35.0	2.210	0.799	2.061	0.012	13
1001	292717.48	202861.92	663.45	CL 4	GNSS	Superior	1001	4/17/2017 9:38	03:00.0	1.435	0.760	1.218	0.015	14
1002	292170.25	231061.77	722.90	CL 5	Optical									
1003	289290.01	260314.48	814.50	CL 3	GNSS	Iron River	1003	4/17/2017 11:39	03:00.0	1.307	0.734	1.082	0.012	17
1004	243726.73	279870.98	989.59	CL 2	GNSS	Iron River	1004	4/17/2017 12:54	03:00.0	1.525	0.715	1.347	0.012	14
1005	273509.17	259941.05	947.47	CL 1	GNSS	Iron River	1005	4/17/2017 13:42	03:00.0	1.874	0.811	1.690	0.017	15
1006	281658.49	261876.41	874.95	CL 4	GNSS	Iron River	1006	4/17/2017 14:05	03:00.0	1.527	0.694	1.360	0.017	16
1007	263100.80	253776.19	1209.30	CL 5	Optical									
1008	257539.98	246367.22	1193.11	CL 2	GNSS	Iron River	1008	4/17/2017 15:43	03:00.0	1.218	0.702	0.995	0.015	16
1009	262283.46	234967.92	928.75	CL 1	GNSS	Iron River	1009	4/17/2017 16:08	03:00.0	1.610	0.953	1.298	0.019	13

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
1010	266094.53	201119.22	823.98	CL 3	GNSS	Superior	1010	4/17/2017 16:55	03:00.0	2.160	0.957	1.937	0.013	11
1011	283228.24	207678.51	707.42	CL 1	GNSS	Superior	1011	4/18/2017 9:11	03:00.0	1.494	0.802	1.264	0.014	14
1012	283431.38	172361.09	672.13	CL 3	GNSS	Superior	1012	4/18/2017 9:38	03:00.0	1.576	0.901	1.294	0.020	14
1013	278701.91	173644.44	691.53	CL 2	GNSS	Superior	1013	4/18/2017 9:50	03:00.0	1.388	0.716	1.189	0.013	15
1014	261517.03	170606.47	758.01	CL 1	GNSS	Superior	1014	4/18/2017 10:25	03:00.0	1.513	0.851	1.251	0.017	12
1015	263665.63	142091.51	688.90	CL 5	GNSS	Superior	1015	4/18/2017 10:58	03:00.0	2.537	1.055	2.308	0.039	12
1016	278059.09	146626.86	677.65	CL 2	GNSS	Superior	1016	4/18/2017 11:23	03:00.0	1.262	0.685	1.060	0.008	17
1017	279336.16	136632.68	685.85	CL 1	GNSS	Superior	1017	4/18/2017 11:46	03:00.0	1.228	0.716	0.998	0.011	16
1018	282045.86	123694.07	651.82	CL 2	GNSS	Superior	1018	4/18/2017 12:13	03:00.0	1.486	0.831	1.231	0.016	14
1019	272044.33	124910.66	739.30	CL 3	GNSS	Superior	1019	4/18/2017 12:29	03:04.0	1.779	0.877	1.549	0.029	13
1020	262380.43	110967.86	813.98	CL 1	GNSS	Superior	1020	4/18/2017 12:47	03:00.0	1.569	0.741	1.383	0.013	14
1021	250148.79	111522.25	815.28	CL 4	GNSS	Superior	1021	4/18/2017 13:17	03:00.0	2.127	0.840	1.954	0.019	13
1022	231645.04	106010.15	875.11	CL 1	GNSS	Superior	1022	4/18/2017 13:40	03:00.0	1.823	0.800	1.640	0.013	13
1023	237807.61	141934.91	978.38	CL 5	Optical									
1024	255400.75	142104.84	709.44	CL 1	GNSS	Superior	1024	4/18/2017 14:58	03:00.0	2.021	0.883	1.817	0.012	12
1025	230760.62	169301.40	1144.10	CL 4	GNSS	Superior	1025	4/18/2017 15:36	03:00.0	1.347	0.727	1.134	0.015	15
1026	248515.98	177730.43	991.67	CL 3	GNSS	Superior	1026	4/18/2017 16:19	03:00.0	1.470	0.781	1.246	0.014	14
1027	246672.23	200855.60	1091.45	CL 1	GNSS	Superior	1027	4/18/2017 16:43	03:00.0	2.162	0.924	1.956	0.014	11

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
1028	239985.72	204377.31	1124.73	CL 2	GNSS	Superior	1028	4/18/2017 16:55	03:00.0	2.119	0.944	1.897	0.016	13
1029	255669.74	223876.94	977.13	CL 2	GNSS	Superior	1029	4/19/2017 8:16	03:00.0	1.820	1.105	1.447	0.019	14
1030	247024.80	220505.75	1092.75	CL 5	Optical									
1031	247034.29	241711.38	1160.03	CL 4	GNSS	Iron River	1031	4/19/2017 9:35	03:00.0	1.267	0.684	1.067	0.014	16
1032	226417.69	229845.55	1177.04	CL 1	GNSS	Iron River	1032	4/19/2017 9:58	03:00.0	1.504	0.791	1.279	0.014	15
1033	230445.48	247903.75	1145.01	CL 2	GNSS	Iron River	1033	4/19/2017 10:13	03:00.0	1.578	0.846	1.332	0.020	15
1034	236025.91	269149.75	1060.37	CL 3	GNSS	Iron River	1034	4/19/2017 10:38	03:00.0	2.438	0.973	2.236	0.017	13
1035	234153.49	280103.44	1080.66	CL 1	GNSS	Iron River	1035	4/19/2017 11:03	03:00.0	2.011	0.946	1.774	0.012	13
1036	204067.99	275606.36	1229.06	CL 5	Optical									
1037	215840.07	265711.52	1221.93	CL 2	GNSS	Iron River	1037	4/19/2017 12:52	03:00.0	1.780	0.855	1.562	0.022	13
1038	207981.22	255011.71	1219.82	CL 1	GNSS	Iron River	1038	4/19/2017 13:06	03:00.0	2.036	0.782	1.880	0.014	13
1039	202693.24	241993.54	1177.23	CL 3	GNSS	Iron River	1039	4/19/2017 13:28	03:00.0	4.439	0.848	4.357	0.012	12
1040	205017.35	228902.18	1221.23	CL 1	GNSS	Iron River	1040	4/19/2017 13:51	03:00.0	2.130	0.787	1.979	0.014	14
1041	215582.60	209560.18	1162.08	CL 4	GNSS	Superior	1041	4/19/2017 14:17	03:00.0	1.336	0.627	1.179	0.017	17
1042	202960.71	197274.27	1196.34	CL 1	GNSS	Superior	1042	4/19/2017 14:41	03:00.0	1.506	0.769	1.295	0.015	14
1043	202409.25	175659.46	1230.02	CL 5	Optical									
1044	216322.81	163012.72	1199.85	CL 1	GNSS	Superior	1044	4/19/2017 16:03	03:00.0	1.614	0.890	1.346	0.016	14
1045	195123.90	148753.95	1234.77	CL 4	GNSS	Dairyland	1045	4/19/2017 16:38	03:00.0	2.047	0.966	1.804	0.009	12
1046	216035.64	132091.68	1221.03	CL 1	GNSS	Superior	1046	4/19/2017 17:03	03:07.0	1.487	0.772	1.272	0.015	14



Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
1047	201409.86	102485.85	1299.30	CL 3	GNSS	Dairyland	1047	4/20/2017 9:15	03:00.0	1.579	0.849	1.331	0.011	14
1048	215872.87	101060.65	1044.32	CL 1	GNSS	Superior	1048	4/20/2017 9:36	03:00.0	1.399	0.765	1.172	0.014	14
1049	221670.02	116984.59	1003.88	CL 2	GNSS	Superior	1049	4/20/2017 9:57	03:00.0	1.532	0.851	1.274	0.019	13
1050	177393.62	143786.90	1310.99	CL 5	Optical									
1051	189630.05	158978.30	1269.82	CL 1	GNSS	Dairyland	1051	4/20/2017 12:06	03:00.0	1.885	0.940	1.634	0.013	12
1052	179026.40	169945.45	1274.29	CL 3	GNSS	Dairyland	1052	4/20/2017 12:30	03:00.0	1.795	0.869	1.571	0.016	12
1053	171686.37	188324.40	1222.86	CL 1	GNSS	Dairyland	1053	4/20/2017 12:58	03:00.0	2.218	0.947	2.005	0.014	11
1054	178790.28	197193.47	1262.31	CL 4	GNSS	Dairyland	1054	4/20/2017 13:19	03:00.0	2.680	1.044	2.468	0.030	10
1055	171079.04	214385.43	1139.53	CL 2	GNSS	Minong	1055	4/20/2017 13:35	03:00.0	1.925	0.810	1.748	0.014	13
1056	190941.86	215399.73	1241.00	CL 1	GNSS	Minong	1056	4/20/2017 13:56	03:00.0	1.846	0.788	1.669	0.021	14
1057	191047.61	234962.99	1068.36	CL 5	Optical									
1058	173997.00	247457.51	1154.88	CL 1	GNSS	Minong	1058	4/20/2017 15:19	03:00.0	1.299	0.724	1.079	0.013	16
1059	189663.30	258845.64	1198.75	CL 4	GNSS	Minong	1059	4/20/2017 15:42	03:00.0	1.215	0.680	1.007	0.015	16
1060	188726.59	280619.37	1201.46	CL 1	GNSS	Iron River	1060	4/20/2017 16:04	03:00.0	1.314	0.768	1.065	0.015	15
1061	173992.08	282311.70	1182.26	CL 2	GNSS	Iron River	1061	4/20/2017 16:24	03:00.0	1.642	0.876	1.389	0.013	14
1062	147602.41	275827.30	1177.38	CL 1	GNSS	Cable	1062	4/20/2017 16:50	03:23.0	1.616	0.883	1.357	0.018	14
1063	154626.98	265286.32	1139.20	CL 3	GNSS	Minong	1063	4/20/2017 17:10	03:00.0	1.304	0.706	1.097	0.017	16
1064	129170.58	280300.39	1158.59	CL 5	Optical									
1065	118045.34	274689.59	1144.33	CL 4	GNSS	Minong	1065	4/21/2017 9:32	03:00.0	1.657	0.831	1.433	0.017	14

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
1066	118469.73	259977.47	1134.28	CL 1	GNSS	Minong	1066	4/21/2017 10:11	03:00.0	3.348	1.063	3.175	0.012	11
1067	123678.56	249266.09	1118.88	CL 2	GNSS	Minong	1067	4/21/2017 10:40	03:00.0	1.794	0.918	1.542	0.012	13
1068	123897.22	238243.94	1067.44	CL 3	GNSS	Minong	1068	4/21/2017 10:53	03:00.0	1.493	0.823	1.246	0.016	13
1069	113021.08	231677.20	1107.03	CL 1	GNSS	Minong	1069	4/21/2017 11:10	03:00.0	1.310	0.740	1.080	0.012	14
1070	136997.54	239464.26	1118.44	CL 1	GNSS	Minong	1070	4/21/2017 11:34	03:00.0	1.316	0.721	1.101	0.013	14
1071	155589.58	250014.21	1145.86	CL 5	Optical									
1072	141834.72	230233.11	1035.15	CL 2	GNSS	Minong	1072	4/21/2017 12:32	03:07.0	1.649	0.764	1.461	0.014	14
1073	132009.69	224177.06	1036.02	CL 2	GNSS	Minong	1073	4/21/2017 12:47	03:00.0	2.012	0.852	1.823	0.014	13
1074	122008.57	116128.75	1143.82	CL 1	GNSS	CHK 404	1074	4/25/2017 8:10	03:00.0	1.566	0.868	1.303	0.010	13
1075	121101.59	105637.12	1133.36	CL 3	GNSS	CHK 404	1075	4/25/2017 9:26	03:00.0	1.354	0.729	1.140	0.017	15
1076	131859.58	112860.75	1168.61	CL 5	GNSS	CHK 404	1076	4/25/2017 9:48	03:00.0	3.055	1.029	2.880	0.023	11
1077	111240.37	126074.04	1100.03	CL 4	GNSS	CHK 404	1077	4/25/2017 10:57	03:00.0	1.550	0.799	1.329	0.014	13
1078	121516.60	133600.34	1122.12	CL 2	GNSS	CHK 404	1078	4/25/2017 11:12	03:00.0	1.654	0.989	1.326	0.009	13
1079	133098.82	127083.65	1157.87	CL 1	GNSS	CHK 404	1079	4/25/2017 11:30	03:00.0	1.589	0.907	1.305	0.011	14
1080	147695.30	116846.64	1204.80	CL 4	GNSS	CHK 404	1080	4/25/2017 12:45	04:19.0	2.379	0.952	2.180	0.012	12
1081	152625.97	133921.03	1245.35	CL 2	GNSS	CHK 404	1081	4/25/2017 13:18	03:00.0	2.395	0.852	2.238	0.012	14
1082	169857.92	137315.52	1292.81	CL 4	GNSS	CHK 404	1082	4/25/2017 14:07	03:00.0	1.455	0.732	1.257	0.016	15
1083	178566.46	119098.41	1298.60	CL 1	GNSS	CHK 404	1083	4/25/2017 14:35	03:00.0	1.955	0.932	1.718	0.020	13

Point ID	Northing	Easting	Elevation	Feat. Code	Observ. Type	GNSS Vector Observ. From Point ID	GNSS Vector Observ. To Point ID	GNSS Vector Observ. Start Time	GNSS Vector Observ. Duration	GNSS Vector Observ. PDOP	GNSS Vector Observ. HDOP	GNSS Vector Observ. VDOP	GNSS Vector Observ. RMS	GNSS Vector Observ. Satellites
1084	151003.36	147351.50	1247.40	CL 3	GNSS	136	1084	4/25/2017 15:39	04:15.0	1.638	0.947	1.343	0.020	13
1085	147076.70	157083.60	1225.64	CL 5	GNSS	136	1085	4/25/2017 15:59	07:17.0	4.003	1.541	3.695	0.026	9
1086	189322.78	108857.43	1273.55	CL 4	GNSS	CHK 404	1086	4/26/2017 9:01	03:40.0	1.714	0.880	1.470	0.020	12
1087	195345.32	119958.99	1273.96	CL 4	GNSS	CHK 404	1087	4/26/2017 9:24	03:00.0	2.268	1.119	1.973	0.023	11
1088	152027.68	189002.23	1131.74	CL 2	GNSS	138	1088	4/26/2017 10:59	03:00.0	1.501	0.797	1.272	0.014	14
1089	136756.00	173480.94	1111.96	CL 4	GNSS	138	1089	4/26/2017 11:22	03:00.0	1.606	0.922	1.315	0.011	13
1090	110742.60	144283.09	1069.77	CL 5	GNSS	CHK 404	1090	4/26/2017 12:48	04:35.0	2.845	1.038	2.674	0.015	13
1091	110499.07	165247.51	1062.20	CL 3	GNSS	CHK 404	1091	4/26/2017 13:12	03:00.0	1.943	0.827	1.759	0.017	13
1092	126440.06	154862.71	1111.05	CL 1	GNSS	CHK 404	1092	4/26/2017 13:32	03:00.0	1.831	0.823	1.636	0.013	12
1093	125909.81	186796.02	1083.75	CL 2	GNSS	Minong	1093	4/26/2017 14:19	03:00.0	1.827	0.891	1.595	0.012	13
1094	105507.41	197628.77	1033.05	CL 2	GNSS	Minong	1094	4/26/2017 14:54	03:00.0	1.745	0.938	1.471	0.012	14
1095	126605.58	214467.68	1095.99	CL 4	GNSS	Minong	1095	4/26/2017 15:28	03:00.0	1.973	1.205	1.563	0.015	12
1096	152157.87	212550.23	1087.02	CL 3	GNSS	Minong	1096	4/26/2017 16:15	03:00.0	2.215	1.039	1.957	0.011	12
1097	315456.13	271188.26	628.61	CL 1	GNSS	Iron River	1097	4/27/2017 9:00	03:00.0	1.324	0.716	1.114	0.014	16
1098	257764.89	282405.49	1060.14	CL 5	GNSS	Iron River	1098	4/27/2017 9:45	03:03.0	1.571	0.858	1.315	0.041	14
1099	217567.11	192814.20	1252.75	CL 1	GNSS	Superior	1099	4/27/2017 10:58	03:00.0	1.361	0.788	1.110	0.013	15
1100	166337.17	227192.45	1103.13	CL 4	GNSS	Minong	1100	4/27/2017 12:02	03:00.0	1.564	0.746	1.374	0.015	14
1101	137012.23	258063.18	1131.43	CL 4	GNSS	Minong	1101	4/27/2017 12:34	03:00.0	1.772	0.713	1.622	0.012	14

Table 4: Optical Measurements' Observation Details and Quality Information

Point ID	Northing	Easting	Elevation	Feature Code	Backsight ID	From Point ID	To Point ID	H. Precision (95%)	V. Precision (95%)	Timestamp
1002	292170.25	231061.77	722.90	CL 5	102	103	1002	0.017	0.003	4/17/2017 11:12
1007	263100.80	253776.19	1209.30	CL 5	106	105	1007	0.016	0.002	4/17/2017 15:25
1023	237807.61	141934.91	978.38	CL 5	111	110	1023	0.017	0.004	4/18/2017 14:29
1030	247024.80	220505.75	1092.75	CL 5	116	115	1030	0.017	0.003	4/19/2017 9:01
1036	204067.99	275606.36	1229.06	CL 5	118	117	1036	0.016	0.002	4/19/2017 12:03
1043	202409.25	175659.46	1230.02	CL 5	121	120	1043	0.016	0.002	4/19/2017 15:26
1050	177393.62	143786.90	1310.99	CL 5	125	124	1050	0.016	0.002	4/20/2017 11:23
1057	191047.61	234962.99	1068.36	CL 5	128	127	1057	0.016	0.001	4/20/2017 14:52
1064	129170.58	280300.39	1158.59	CL 5	132	131	1064	0.016	0.002	4/21/2017 9:10
1071	155589.58	250014.21	1145.86	CL 5	134	133	1071	0.016	0.002	4/21/2017 12:11

Table 5: Douglas County Geodetic Control and NGS Monuments Check Shots' Results

HEI Check Shots on Control Points								Control Points				
Point ID	(US Survey Feet)			Feature Code	Difference from Control			Point ID	(US Survey Feet)			
	Northing	Easting	Elevation		Δ Northing	Δ Easting	Δ Elevation		Northing	Easting	Elevation	Feature Code
101	287995.32	179687.22	649.96	CHK 446	0.01	-0.07	-0.05	400	119303.31	154023.03	1066.64	GEO CTRL 400
104	254259.16	256236.54	1135.92	CHK 443	0.02	-0.04	0.06	402	131940.31	281237.16	1154.20	GEO CTRL 402
107	287339.51	172656.41	648.50	CHK 447	-0.05	-0.07	-0.17	404	137043.15	260237.42	1133.52	GEO CTRL 404
108	278805.88	223554.41	790.32	CHK 432	0.02	-0.07	-0.10	408	174043.29	254920.98	1174.64	GEO CTRL 408
109	283708.75	132177.58	667.09	CHK 431	-0.21	-0.14	0.07	409	169874.15	132732.22	1273.10	GEO CTRL 409

HEI Check Shots on Control Points								Control Points				
112	258000.46	198650.80	950.34	CHK 438	-0.05	-0.20	-0.11	410	200395.32	107586.18	1277.21	GEO CTRL 410
113	258000.51	198650.81	950.31	CHK 438	-0.10	-0.21	-0.08	411	226201.10	222033.10	1168.39	GEO CTRL 411
114	255274.74	227296.29	987.01	CHK 504	0.05	-0.14	0.03	420	121922.61	115724.67	1139.33	GEO CTRL 420
119	215759.82	253934.77	1137.47	CHK 441	0.00	0.00	0.19	421	147670.84	217405.20	1088.45	GEO CTRL 421
122	242303.57	142914.28	851.88	CHK 430	-0.29	0.02	0.00	424	117510.18	186917.85	1056.91	GEO CTRL 424
123	200395.36	107586.19	1277.06	CHK 410	-0.04	-0.01	0.15	426	121479.77	133825.05	1118.12	GEO CTRL 426
126	171173.41	212965.73	1140.16	CHK 427	0.00	0.01	0.16	427	171173.41	212965.74	1140.32	GEO CTRL 427
129	174043.26	254920.98	1174.49	CHK 408	0.03	0.00	0.16	428	147533.42	133841.41	1225.87	GEO CTRL 428
130	131940.21	281237.15	1154.06	CHK 402	0.11	0.01	0.14	430	242303.28	142914.30	851.88	GEO CTRL 430
135	147670.83	217405.17	1088.27	CHK 421	0.01	0.03	0.18	431	283708.54	132177.44	667.16	GEO CTRL 431
137	147789.73	144966.62	1235.42	CHK WDOT 8B57			-0.06	432	278805.90	223554.34	790.22	GEO CTRL 432
140	117510.18	186917.78	1056.72	CHK 424	0.00	0.07	0.19	434	231611.86	110981.01	858.75	GEO CTRL 434
141	147606.60	198970.22	1070.70	CHK 139	0.01	-0.05	0.09	438	258000.41	198650.60	950.23	GEO CTRL 438
142	147670.84	217405.20	1088.18	CHK 421	0.00	0.00	0.27	440	289408.24	245513.10	779.70	GEO CTRL 440
143	226201.02	222033.04	1168.24	CHK 411	0.08	0.06	0.16	441	215759.82	253934.77	1137.66	GEO CTRL 441
144	137043.19	260237.41	1133.28	CHK 404	-0.04	0.01	0.24	443	254259.18	256236.50	1135.98	GEO CTRL 443
								446	287995.33	179687.15	649.91	GEO CTRL 446
				Sum of Elev. Diff.			1.49	447	287339.46	172656.34	648.33	GEO CTRL 447
								500	298825.01	280260.97	787.36	GEO CTRL 500
				Average Elevation Diff.			0.07	504	255274.79	227296.15	987.04	GEO CTRL 504
								139	147606.61	198970.17	1070.79	RP NAIL
											1235.36	NGS_8B57



4.4 APPENDIX D: FLASH DRIVE CONTAINING DATA SHEETS FOR CONTROL