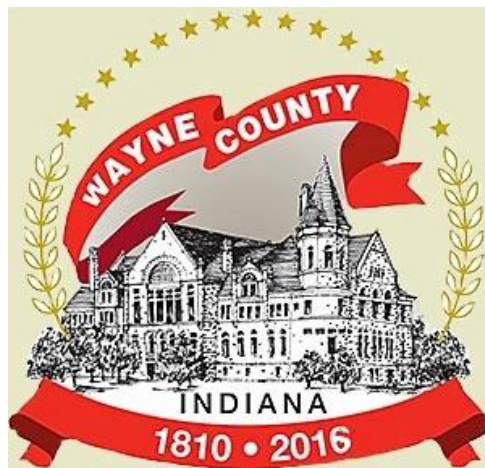


LiDAR Accuracy Assessment



Wayne County,
Indiana for
LiDAR Acquired Spring 2017

Prepared by
Jeff Padgett CP, PSM
August 31, 2017

Summary

GRW was contracted in the Spring of 2017 to develop elevation data to support 2' contours for Wayne County, Indiana. The project included the acquisition of LiDAR data utilizing an Optech Gemini sensor. Data was acquired Spring 2017.

Control points were field surveyed to be used in the calibration and adjustment of the LiDAR dataset as part of the original project. Validation points to be used in the reporting of RMSE_z, Supplemental, NVA and VVA Accuracies were surveyed in March 2017. The validation points surveyed in March 2017 serve as the basis for the accuracy assessment contained in this report.

The charts and statistics on the following pages were derived by comparing the final project DEM (generated from bare earth LiDAR) to the surveyed XYZ position of each point. Comparisons were made using the TerraModel software, comparing the surveyed position to the TIN generated from the DEM.

The project was delivered to the client in NGVD88 vertical datum, US Survey Foot. All XYZ coordinates reported herein are based on NAD88 Indiana East horizontal and NGVD88 vertical datums.

Accuracy Statements

Tested 6.94944 cm **RMSE_z** open terrain using urban and ground control validation points.

Tested 13.80 cm **Non-Vegetated Accuracy** at 95th percentile in open terrain using urban and ground control points with RMSE_z * 1.9600.

Tested 0.65072 feet **supplemental vertical accuracy** at 95th percentile in Bare Earth category.

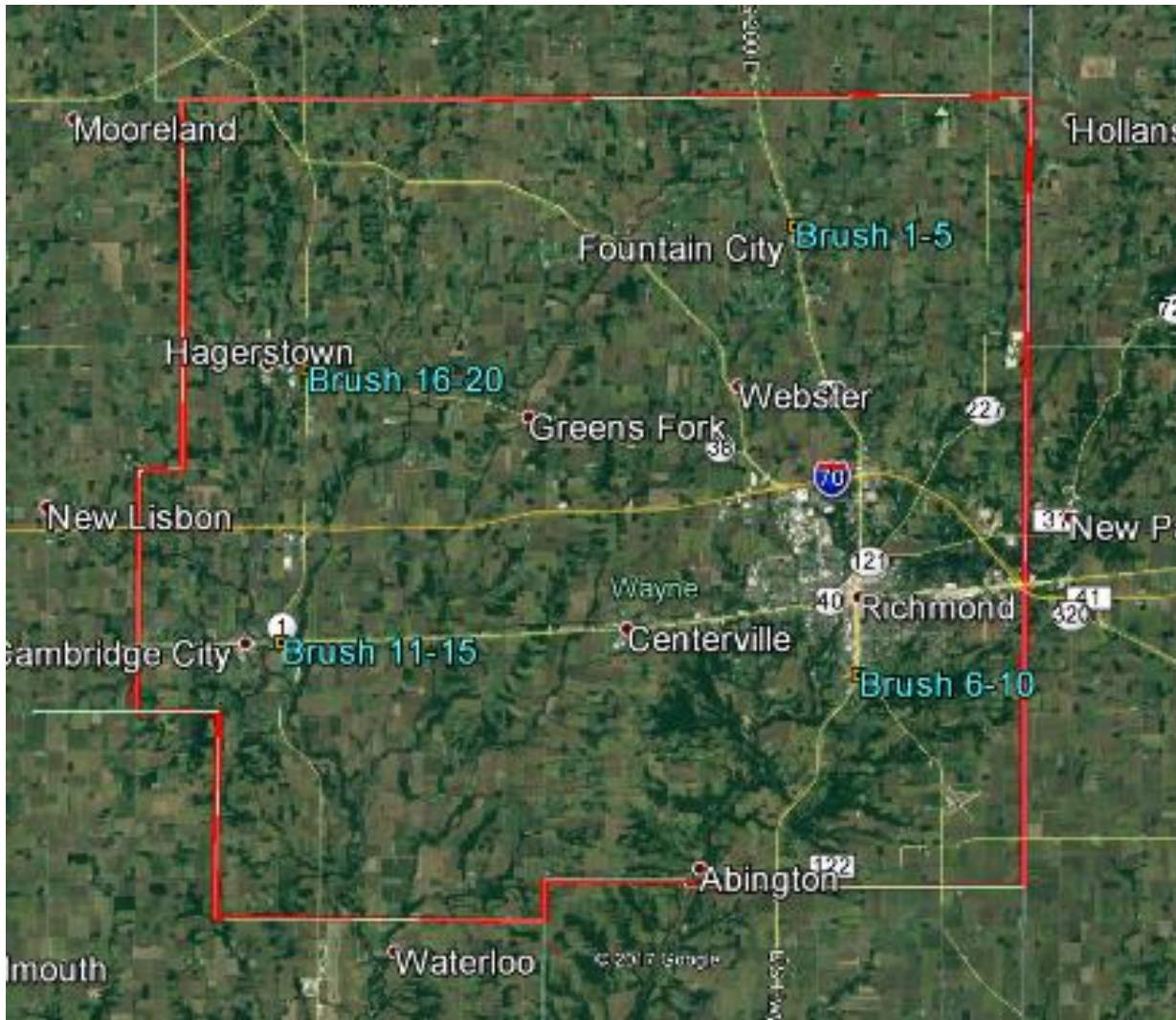
Tested 0.46844 feet **supplemental vertical accuracy** at 95th percentile in Urban category.

Tested 1.3426 feet **supplemental vertical accuracy** at 95th percentile in Brush category.

Tested 1.39552 feet **supplemental vertical accuracy** at 95th percentile in Forested Area category.

Tested 1.00156 feet **supplemental vertical accuracy** at 95th percentile in High Grass category.

Tested 38.23 cm **vegetated vertical accuracy** at 95th percentile in vegetated areas including Forested, High Grass, and Brush categories with RMSE_z * 1.9600.



Location of points used in calculation of NVA, SVA, and VVA. Project

Boundary is shown as a red polygon.

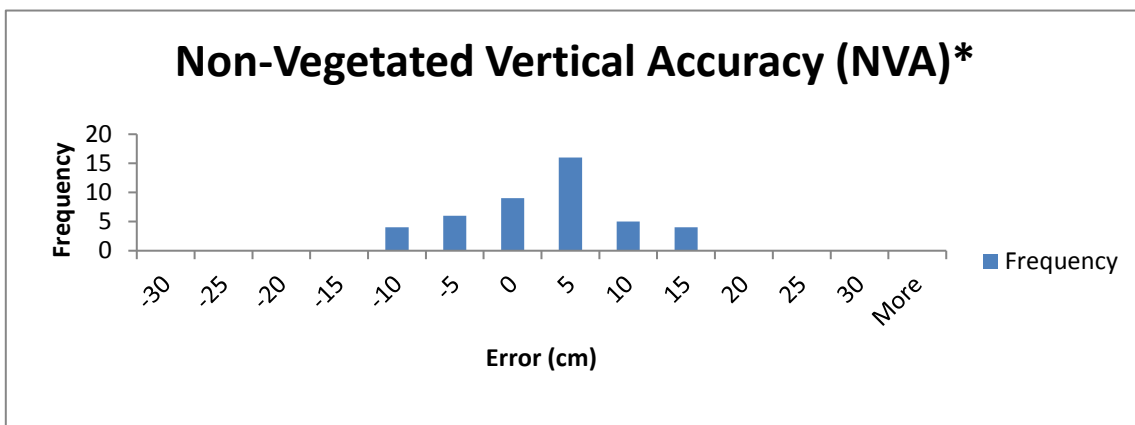
At each location, a point was collected for each land cover type in 4 well distributed areas throughout the county. For example, Brush points 1 through 5 were surveyed near Fountain City and Brush points 6 through 10 south of Richmond. In all a total of 20 brush points were surveyed and the same was true for the four other vegetation categories such as: urban, open, tall grass and forested. A total of 100 validation points were surveyed to assess the LiDAR accuracy.

Density Calculation

Five (5) randomly chosen 5,000' x 5,000' .las tiles of classified LiDAR data were chosen for this calculation. The tiles were composed of complete calibrated flight lines having 50% overlap and in some cases including a cross-flight. The density was calculated in tiles formatted in meters as the unit of measure with LAS Info statistics queried from LAS Tools. The resulting chart indicated a density of 3.468 points using all points and a density of 2.62 points per square meter comparing only the last return.

TILE	ALL DENSITY	LAST DENSITY	ALL SPACING	LAST SPACING	
15	2.36	2.25	0.65	0.67	Meters
100	2.21	2.07	0.67	0.7	Meters
150	4.75	3.2	0.46	0.56	Meters
300	4.39	2.92	0.48	0.58	Meters
500	3.63	2.66	0.52	0.61	Meters
AVG	3.468	2.62	0.556	0.624	Meters

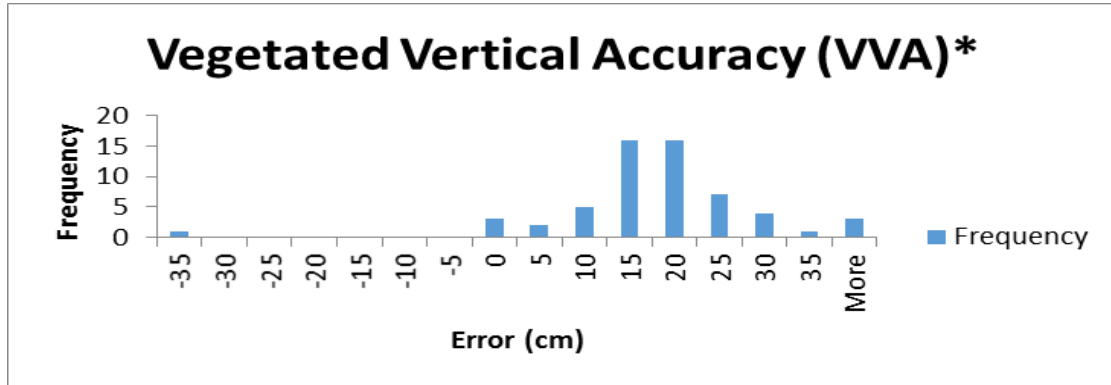
Measured by Las Info from Las Tools.
 Ran on tiles that had been converted to meters.



* Calculated with Urban Area and Ground Control Validation Points

Number	Easting	Northing	Elevation	DTM Z	Errors (ft)	Errors (cm)
UR 13	466909.61	1662270.13	933.26	removed	*	
LID 7	562409.41	1716146.82	1139.34	1139.8	0.46	14.0208
UR 2	538017.79	1713458.73	1086.98	1087.43	0.45	13.716
ADD 108	494017.44	1663793.38	964.681	965.13	0.449	13.68552
UR 11	467149.79	1662277.41	932.15	932.49	0.34	10.3632
LID 12	557157.07	1638782.21	1126.98	1127.27	0.29	8.8392
UR 15	466957.36	1662604.06	933.84	934.08	0.24	7.3152
ADD 109	542905.45	1674260.73	979.023	979.26	0.237	7.22376

LID 10	547182.8	1661329.71	1023.05	1023.28	0.23	7.0104	
OP 17	537037.25	1717588.82	1120.46	1120.65	0.19	5.7912	
UR 5	537087.48	1714919.59	1105.36	1105.52	0.16	4.8768	
UR 3	538440.33	1713779.63	1087.77	1087.92	0.15	4.572	
UR 14	466741.33	1662262.55	935.05	935.19	0.14	4.2672	
UR 1	537413.76	1717451.59	1117.97	1118.1	0.13	3.9624	
ADD 106	525854.46	1688449.04	1028.215	1028.34	0.125	3.81	
UR 4	538166.04	1715255.48	1103.36	1103.48	0.12	3.6576	
UR 18	470025.51	1698452.08	1005.2	1005.31	0.11	3.3528	
LID 5	474306	1729082.46	1083.64	1083.74	0.1	3.048	
OP 11	559355.22	1670178.88	1096.77	1096.86	0.09	2.7432	
LID 2	471807.44	1662734.36	968.75	968.83	0.08	2.4384	
OP 10	472024.37	1661263.77	961.22	961.3	0.08	2.4384	
LID 11	556989.29	1648652.48	1113.3	1113.37	0.07	2.1336	
OP 13	558267.48	1669214.79	1081.36	1081.41	0.05	1.524	
UR 12	467012.44	1662267.21	934.15	934.19	0.04	1.2192	
F 277	557135.36	1642897.61	1121.91	1121.95	0.04	1.2192	
ADD 101	499926.55	1727750.85	1182.266	1182.28	0.014	0.42672	
ADD 102	533509.71	1728930.57	1209.991	1209.99	-0.001	-0.03048	
UR 9	516130.35	1664988.84	1007.76	1007.71	-0.05	-1.524	
ADD 105	503230.3	1679073.25	1093.713	1093.66	-0.053	-1.61544	
ADD 110	517590.42	1635307.35	1055.304	1055.25	-0.054	-1.64592	
UR 20	469992.95	1698572.2	1007.47	1007.41	-0.06	-1.8288	
LID 9	563023.71	1677282.64	1004.87	1004.77	-0.1	-3.048	
ADD 103	505405.55	1711135	1136.431	1136.32	-0.111	-3.38328	
UR 16	470016.84	1698310.31	1002.89	1002.74	-0.15	-4.572	
UR 17	470022.18	1698391.58	1004.32	1004.16	-0.16	-4.8768	
LID 3	474840.87	1687314.98	1045.44	1045.2	-0.24	-7.3152	
UR 8	516764.13	1665042.24	1009.51	1009.27	-0.24	-7.3152	
UR 19	469981.71	1698515.03	1007.47	1007.22	-0.25	-7.62	
UR 7	516386.79	1665093.32	1011.51	1011.25	-0.26	-7.9248	
LID 6	562518.85	1730035.04	1204.77	1204.5	-0.27	-8.2296	
LID 4	474700.4	1709121.86	1040.49	1040.2	-0.29	-8.8392	
LID 1	476875.09	1633880.32	882.84	882.49	-0.35	-10.668	
UR 6	516433.46	1665339.79	1007.39	1007.02	-0.37	-11.2776	
ADD 104	458559.62	1676088.22	1008.764	1008.39	-0.374	-11.39952	
UR 10	515937.95	1665281.22	996.62	996.15	-0.47	-14.3256	
LID 8	562278.65	1701490.1	1096.01	removed	*		
<i>*Blunder, not included in accuracy calculations</i>					Average	0.012	0.36576
					Minimum	-0.47	-14.3256
					Maximum	0.46	14.0208
					Std Dev	0.231	7.04088
					RMSE	0.228	6.94944
					95th	0.45276	13.8001248



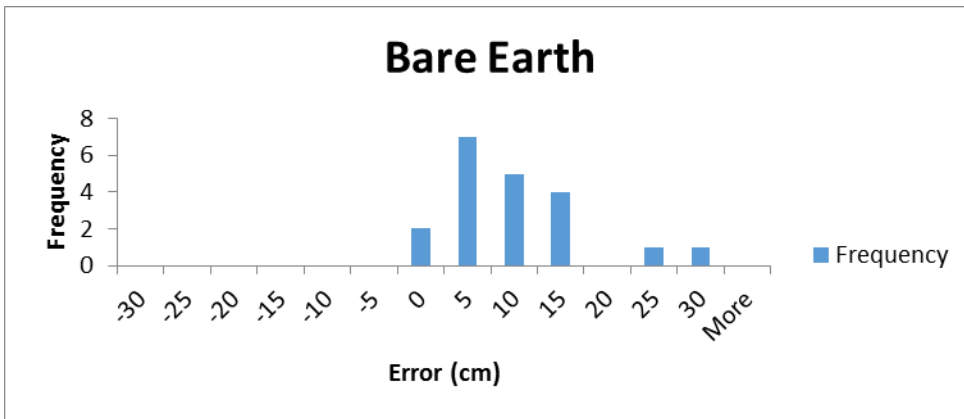
* Calculated with all vegetation validation points

Class	Num	Easting	Northing	Elevation	DTM Z	Error (ft)	Error (cm)
FA	11	562181.13	1675185.89	1004.24	removed	*	
FA	20	537164.93	1714933.99	1104.93	1106.2	1.27	38.7096
BR	6	546157.33	1659536.62	974.91	976.06	1.15	35.052
BR	13	472087.82	1663421.78	968.84	969.99	1.15	35.052
FA	18	538011.23	1713304.98	1084.45	1085.52	1.07	32.6136
BR	11	471836.42	1663983.2	965.36	966.34	0.98	29.8704
BR	3	537082.37	1717329.96	1114.64	1115.62	0.98	29.8704
FA	4	475569.43	1695857.54	1068.2	1069.07	0.87	26.5176
TG	11	563878.91	1671742.24	1054.86	1055.7	0.84	25.6032
TG	8	471904.99	1661331.73	960.27	961.07	0.8	24.384
BR	19	475463.7	1695195.17	1051.68	1052.43	0.75	22.86
BR	2	537148.17	1717278.91	1114.57	1115.32	0.75	22.86
BR	14	472339.95	1663085.91	965.3	966.02	0.72	21.9456
BR	4	537019.63	1717427.05	1116.32	1117.01	0.69	21.0312
TG	12	565682.6	1671099.66	1068.83	1069.52	0.69	21.0312
TG	6	471778.54	1663944.28	967.21	967.9	0.69	21.0312
BR	7	546214.01	1658921.31	970.36	971.01	0.65	19.812
FA	14	562231.69	1675734.2	978.79	979.43	0.64	19.5072
FA	19	538537.65	1713827.83	1086.94	1087.58	0.64	19.5072
BR	5	537218.03	1717826.79	1121.25	1121.88	0.63	19.2024
FA	6	471714.88	1663823.04	962.21	962.84	0.63	19.2024
BR	1	537460.9	1717539.04	1116.16	1116.79	0.63	19.2024
TG	16	537394.52	1717391.98	1116.38	1117	0.62	18.8976
TG	4	475306.32	1695010.02	1046.67	1047.29	0.62	18.8976
FA	17	537035.51	1717415.17	1116.13	1116.71	0.58	17.6784
FA	15	562067.64	1675487.5	985.54	986.11	0.57	17.3736
FA	13	562379.07	1675390.29	991.73	992.29	0.56	17.0688
TG	2	475998.26	1695825.99	1069.61	1070.16	0.55	16.764
FA	12	562318.17	1675146.24	1010.82	1011.36	0.54	16.4592
TG	5	475441.6	1695161.75	1050.14	1050.67	0.53	16.1544

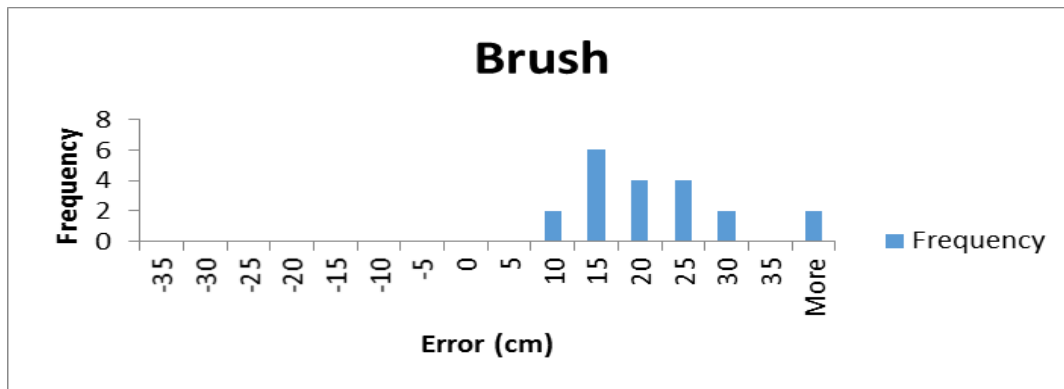
BR	20	475609.74	1695269.03	1056.2	1056.7	0.5	15.24
TG	20	538013.2	1713409.96	1085.28	1085.78	0.5	15.24
BR	15	472108.5	1661418.85	960.48	960.97	0.49	14.9352
TG	3	476195.33	1695837.65	1078.38	1078.85	0.47	14.3256
BR	18	475332.9	1695032.83	1047.18	1047.64	0.46	14.0208
FA	7	471969.22	1663099.04	971.09	971.55	0.46	14.0208
FA	10	467743.99	1663587.09	924.79	925.23	0.44	13.4112
TG	10	466437.99	1661953.99	938.04	938.47	0.43	13.1064
FA	9	467541.76	1663663.39	925.02	925.43	0.41	12.4968
BR	8	546172.16	1658717.76	969.13	969.53	0.4	12.192
BR	9	546170.84	1658675.29	968.95	969.35	0.4	12.192
TG	13	559888.06	1671343.9	1063.13	1063.53	0.4	12.192
TG	1	475617.25	1695703.04	1061.59	1061.98	0.39	11.8872
TG	7	470353.5	1662375.28	939.03	939.42	0.39	11.8872
BR	16	476094.99	1695895.45	1072.09	1072.46	0.37	11.2776
TG	17	537265.83	1717370.94	1115.59	1115.96	0.37	11.2776
BR	17	475307.18	1695830.78	1078.18	1078.55	0.37	11.2776
TG	18	537031.23	1717492.5	1117.68	1118.03	0.35	10.668
BR	12	471960.65	1663903.11	972.46	972.78	0.32	9.7536
BR	10	546270.58	1658668	967.63	967.93	0.3	9.144
TG	9	471926.5	1661979.75	973.74	974.04	0.3	9.144
TG	14	561578.88	1671440.69	1048.44	1048.73	0.29	8.8392
FA	16	537484.88	1717601.46	1115.41	1115.58	0.17	5.1816
TG	15	563390.85	1669843.5	1036.69	1036.82	0.13	3.9624
TG	19	537268.57	1717701.23	1121.72	1121.8	0.08	2.4384
FA	2	475663.07	1695603.58	1059.84	1059.83	-0.01	-0.3048
FA	1	475612.13	1695761.14	1063.99	1063.91	-0.08	-2.4384
FA	3	475804.33	1695839.26	1068.21	1068.1	-0.11	-3.3528
FA	8	466539.73	1661941.02	941.12	939.54	-1.58	-48.1584
FA	5	475391.98	1695929.08	1079.2	outside	*	

Blunder, point excluded from accuracy calculations

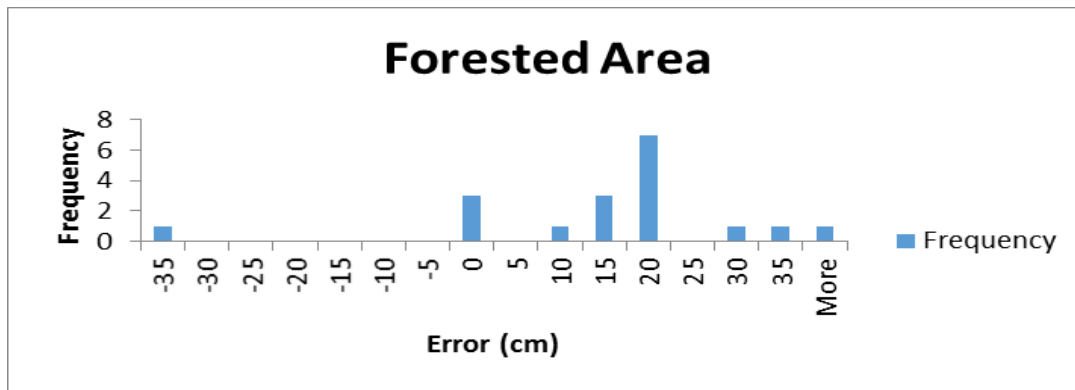
Average	0.503	15.33144
Minimum	-1.58	-48.1584
Maximum	1.27	38.7096
Std Dev	0.398	12.13104
RMSE	0.64	19.5072
95th	1.2544	38.23



Number	Easting	Northing	Elevation	DTM Z	Error (ft)	Error (cm)
OP 8	472128.3	1663785	974.11	974.95	0.84	25.6032
OP 9	472009.2	1663285	957.12	957.85	0.73	22.2504
OP 6	471611.9	1663810	957.1	957.53	0.43	13.1064
OP 2	472008	1699930	979.06	979.44	0.38	11.5824
OP 7	472028.8	1663987	969.31	969.68	0.37	11.2776
OP 16	537433.8	1717573	1117.44	1117.79	0.35	10.668
OP 12	559205.1	1669911	1092.22	1092.5	0.28	8.5344
OP 20	537239.7	1714909	1103.58	1103.85	0.27	8.2296
OP 19	538481.3	1713819	1087.44	1087.71	0.27	8.2296
OP 18	538024.6	1713550	1085.55	1085.8	0.25	7.62
OP 17	537037.3	1717589	1120.46	1120.65	0.19	5.7912
OP 1	472201.3	1700411	982.75	982.89	0.14	4.2672
OP 11	559355.2	1670179	1096.77	1096.86	0.09	2.7432
OP 10	472024.4	1661264	961.22	961.3	0.08	2.4384
OP 5	471784.6	1698773	978.63	978.71	0.08	2.4384
OP 13	558267.5	1669215	1081.36	1081.41	0.05	1.524
OP 3	471694.3	1699721	980.93	980.96	0.03	0.9144
OP 4	471605.4	1699075	980.16	980.18	0.02	0.6096
OP 15	559834.2	1669413	1124.32	1124.25	-0.07	-2.1336
OP 14	558911.5	1669120	1089.92	1089.85	-0.07	-2.1336
Average					0.236	7.19328
Minimum					-0.07	-2.1336
Maximum					0.84	25.6032
Std dev					0.25	7.62
RMSE					0.332	10.11936
95th					0.65072	19.83395



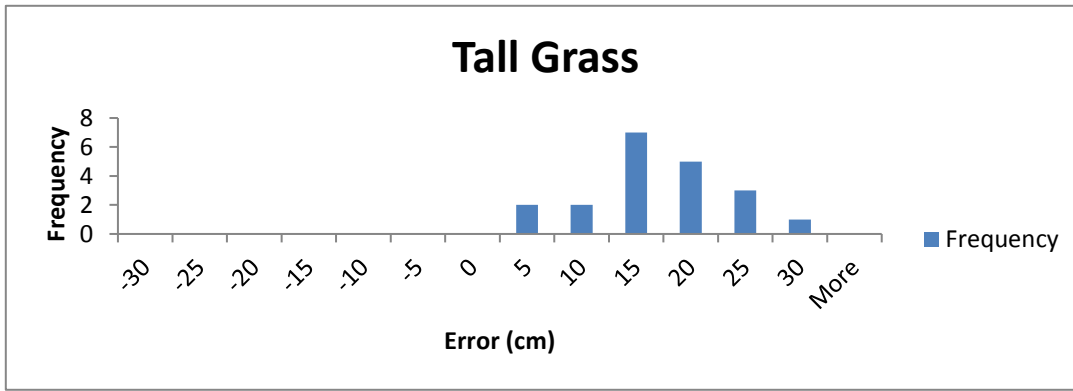
Number	Easting	Northing	Elevation	DTM Z	Error (ft)	Error (cm)
BR 6	546157.33	1659536.6	974.91	976.06	1.15	35.052
BR 13	472087.82	1663421.8	968.84	969.99	1.15	35.052
BR 11	471836.42	1663983.2	965.36	966.34	0.98	29.8704
BR 3	537082.37	1717330	1114.64	1115.62	0.98	29.8704
BR 19	475463.7	1695195.2	1051.68	1052.43	0.75	22.86
BR 2	537148.17	1717278.9	1114.57	1115.32	0.75	22.86
BR 14	472339.95	1663085.9	965.3	966.02	0.72	21.9456
BR 4	537019.63	1717427.1	1116.32	1117.01	0.69	21.0312
BR 7	546214.01	1658921.3	970.36	971.01	0.65	19.812
BR 5	537218.03	1717826.8	1121.25	1121.88	0.63	19.2024
BR 1	537460.9	1717539	1116.16	1116.79	0.63	19.2024
BR 20	475609.74	1695269	1056.2	1056.7	0.5	15.24
BR 15	472108.5	1661418.9	960.48	960.97	0.49	14.9352
BR 18	475332.9	1695032.8	1047.18	1047.64	0.46	14.0208
BR 8	546172.16	1658717.8	969.13	969.53	0.4	12.192
BR 9	546170.84	1658675.3	968.95	969.35	0.4	12.192
BR 16	476094.99	1695895.5	1072.09	1072.46	0.37	11.2776
BR 17	475307.18	1695830.8	1078.18	1078.55	0.37	11.2776
BR 12	471960.65	1663903.1	972.46	972.78	0.32	9.7536
BR 10	546270.58	1658668	967.63	967.93	0.3	9.144
Average					0.635	19.3548
Minimum					0.3	9.144
Maximum					1.15	35.052
Std dev					0.265	8.0772
RMSE					0.685	20.8788
95th					1.3426	40.92245



Number	Easting	Northing	Known Z	Laser Z	Error (ft)	Error (cm)
FA 11	562181.13	1675185.9	1004.24	removed	*	
FA 20	537164.93	1714934	1104.93	1106.2	1.27	38.7096
FA 18	538011.23	1713305	1084.45	1085.52	1.07	32.6136
FA 4	475569.43	1695857.5	1068.2	1069.07	0.87	26.5176
FA 14	562231.69	1675734.2	978.79	979.43	0.64	19.5072
FA 19	538537.65	1713827.8	1086.94	1087.58	0.64	19.5072
FA 6	471714.88	1663823	962.21	962.84	0.63	19.2024
FA 17	537035.51	1717415.2	1116.13	1116.71	0.58	17.6784
FA 15	562067.64	1675487.5	985.54	986.11	0.57	17.3736
FA 13	562379.07	1675390.3	991.73	992.29	0.56	17.0688
FA 12	562318.17	1675146.2	1010.82	1011.36	0.54	16.4592
FA 7	471969.22	1663099	971.09	971.55	0.46	14.0208
FA 10	467743.99	1663587.1	924.79	925.23	0.44	13.4112
FA 9	467541.76	1663663.4	925.02	925.43	0.41	12.4968
FA 16	537484.88	1717601.5	1115.41	1115.58	0.17	5.1816
FA 2	475663.07	1695603.6	1059.84	1059.83	-0.01	-0.3048
FA 1	475612.13	1695761.1	1063.99	1063.91	-0.08	-2.4384
FA 3	475804.33	1695839.3	1068.21	1068.1	-0.11	-3.3528
FA 8	466539.73	1661941	941.12	939.54	-1.58	-48.1584
FA 5	475391.98	1695929.1	1079.2	outside	*	

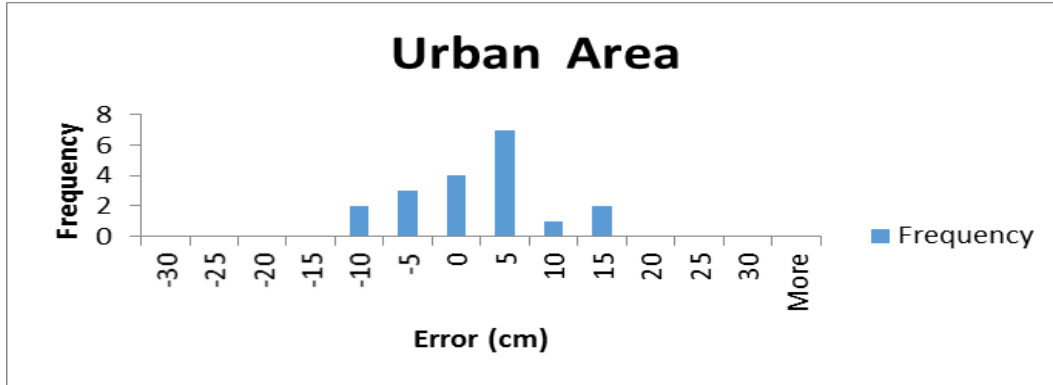
Blunder, not included in accuracy calculations

Average	0.393	11.97864
Minimum	-1.58	-48.1584
Maximum	1.27	38.7096
Std dev	0.611	18.62328
RMSE	0.712	21.70176
95th	1.39552	42.5354496



Number	Easting	Northing	Elevation	DTM Z	Error (ft)	Error (cm)
TG 11	563878.91	1671742.2	1054.86	1055.7	0.84	25.6032
TG 8	471904.99	1661331.7	960.27	961.07	0.8	24.384
TG 12	565682.6	1671099.7	1068.83	1069.52	0.69	21.0312
TG 6	471778.54	1663944.3	967.21	967.9	0.69	21.0312
TG 16	537394.52	1717392	1116.38	1117	0.62	18.8976
TG 4	475306.32	1695010	1046.67	1047.29	0.62	18.8976
TG 2	475998.26	1695826	1069.61	1070.16	0.55	16.764
TG 5	475441.6	1695161.8	1050.14	1050.67	0.53	16.1544
TG 20	538013.2	1713410	1085.28	1085.78	0.5	15.24
TG 3	476195.33	1695837.7	1078.38	1078.85	0.47	14.3256
TG 10	466437.99	1661954	938.04	938.47	0.43	13.1064
TG 13	559888.06	1671343.9	1063.13	1063.53	0.4	12.192
TG 1	475617.25	1695703	1061.59	1061.98	0.39	11.8872
TG 7	470353.5	1662375.3	939.03	939.42	0.39	11.8872
TG 17	537265.83	1717370.9	1115.59	1115.96	0.37	11.2776
TG 18	537031.23	1717492.5	1117.68	1118.03	0.35	10.668
TG 9	471926.5	1661979.8	973.74	974.04	0.3	9.144
TG 14	561578.88	1671440.7	1048.44	1048.73	0.29	8.8392
TG 15	563390.85	1669843.5	1036.69	1036.82	0.13	3.9624
TG 19	537268.57	1717701.2	1121.72	1121.8	0.08	2.4384

Average	0.472	14.38656
Minimum	0.08	2.4384
Maximum	0.84	25.6032
Std dev	0.201	6.12648
RMSE	0.511	15.57528
95th	1.00156	30.527549



Number	Easting	Northing	Known Z	DTM Z	Error (ft)	Error (cm)
UR 13	466909.61	1662270.13	933.26	removed	*	
UR 2	538017.79	1713458.73	1086.98	1087.43	0.45	13.716
UR 11	467149.79	1662277.41	932.15	932.49	0.34	10.3632
UR 15	466957.36	1662604.06	933.84	934.08	0.24	7.3152
UR 5	537087.48	1714919.59	1105.36	1105.52	0.16	4.8768
UR 3	538440.33	1713779.63	1087.77	1087.92	0.15	4.572
UR 14	466741.33	1662262.55	935.05	935.19	0.14	4.2672
UR 1	537413.76	1717451.59	1117.97	1118.1	0.13	3.9624
UR 4	538166.04	1715255.48	1103.36	1103.48	0.12	3.6576
UR 18	470025.51	1698452.08	1005.2	1005.31	0.11	3.3528
UR 12	467012.44	1662267.21	934.15	934.19	0.04	1.2192
UR 9	516130.35	1664988.84	1007.76	1007.71	-0.05	-1.524
UR 20	469992.95	1698572.2	1007.47	1007.41	-0.06	-1.8288
UR 16	470016.84	1698310.31	1002.89	1002.74	-0.15	-4.572
UR 17	470022.18	1698391.58	1004.32	1004.16	-0.16	-4.8768
UR 8	516764.13	1665042.24	1009.51	1009.27	-0.24	-7.3152
UR 19	469981.71	1698515.03	1007.47	1007.22	-0.25	-7.62
UR 7	516386.79	1665093.32	1011.51	1011.25	-0.26	-7.9248
UR 6	516433.46	1665339.79	1007.39	1007.02	-0.37	-11.2776
UR 10	515937.95	1665281.22	996.62	996.15	-0.47	-14.3256

Blunder, point not included in accuracy calculations

Average	-0.007	-0.21336
Minimum	-0.47	-14.3256
Maximum	0.45	13.716
Std dev	0.246	7.49808
RMSE	0.239	7.28472
95th	0.46844	14.278051

LiDAR Flight Mission – Summary

LiDAR data was acquired during the late winter and early spring during the period when vegetation was primarily dormant. Using a Cessna 206 single engine aircraft, LiDAR was acquired with an Optech ALTM Gemini LiDAR sensor on board. The objective was USGS QL2 Lidar data suitable for a 2-foot contour at an altitude of 1400 meters above average ground level. Overlap between adjacent flight lines was 50% with line spacing designed to be 1315 feet per swath. The speed of the aircraft was at 120 knots and the resultant density was designed for 2 points per square meter including the overlapping data from adjacent flight lines.

LiDAR Flight Map

Wayne County



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, AeroGRID, IGN, SITA, Airphoto (FA), USDA, IGN, and GeoEye Community

Legend

- QL2 LIDAR Lines
- LIDAR_Extents

1 inch = 17,000 feet



Flight Parameters			
Accuracy	2' Class	RTK	0.1
Altitude (m)	1400	RTK	0.1
Overlap (%)	50	PPM	3
Speed (km/h)	110	# of Lines	90
Line Spacing (m)	1.13	Line Miles	2.90

Flight Parameters: 21_Survey_MSDL.jpg