STARR
Strategic Alliance for Risk Reduction

Racine County, WI

Post-Flight Aerial Acquisition and Calibration Report

February 2014

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Section 1 Overview

Vendor Contact Information:

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Purpose: Quantum Spatial acquired highly accurate Light Detection and Ranging (LiDAR) data for an area that consisted of approximately 332 square miles of Racine County, Wisconsin, for the Southeastern Wisconsin Regional Planning Commission (SEWRPC) and Racine County. SEWRPC also contracted Quantum Spatial to process a portion of the data to fully classified LAS data. Subsequently, FEMA Region V contracted STARR (and their subcontractor Quantum Spatial) to process the remaining portion of the data. See Section 5 for more information.

Location: The project area includes approximately 332 square miles of Racine County, Wisconsin. Figure 1.1 provides a graphic reference for the project area. Table 1.1 provides the coordinate references.

Figure 1.1 Racine County Project Area

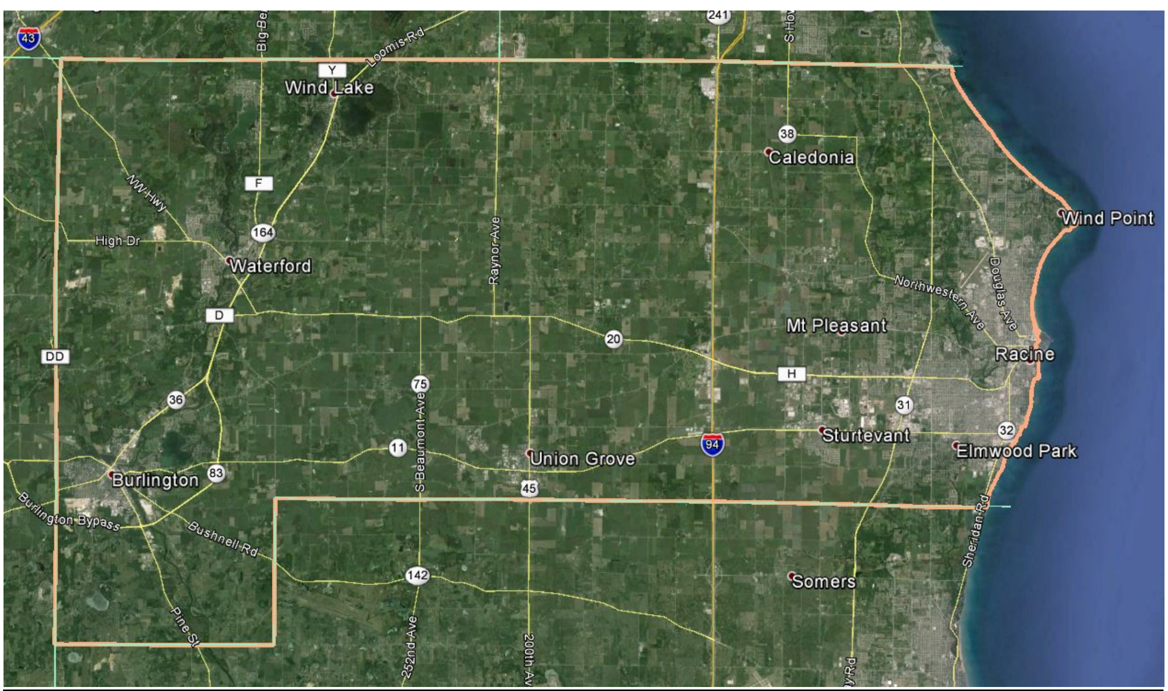


Table 1.1 Racine County Project Extents

Project extents		
North	42° 50’36’’ N	088° 04’12’’ W
East	42° 46’52’’ N	087° 45’26’’ W
South	42° 36’39’’ N	088° 14’30’’ W
West	42° 43’37’’ N	088° 18’26’’ W

Section 2 Acquisition

LiDAR System Specifications: The LiDAR was collected under the requirements for collection of mass points to support the construction of 2-foot contours. The parameters were determined as presented in Table 2.1.

Table 2.1 LiDAR System Specification Table

Flying Height	1700 meters
Laser Pulse Rate	70kHz
Mirror Scan Frequency	32 Hz
Scan Angle	(+/-) 22°
Side Lap	55%
Ground Speed	160 knots
Nominal Point Spacing	1.3 meter

Base Station Information: All missions were processed using Wisconsin CORS base stations. The Racine Area 2 utilized *KEHA* (Kenosha, WI), SIWI (Milwaukee, WI), and SHAN (Sheboygan, WI). Table 2.2 provides the base station information for the project area. The maximum extent of the baseline collection area was approximately 50 km from a base. The maximum PDOP for bases was 3.6 as shown in the PDOP graphs (see Section 3). Figure 2.1 provides a graphic of the base station locations relative to the collection area.

Table 2.2 Base Station Location

POINT	LAT (N)	LONG (W)	HEIGHT (Ellipsoid)
KEHA	42°33'32.29917"	87°55'09.15144"	204.203m
SHAN	43°44'51.46198"	87°44'05.22551"	152.946m
SIWI	42°52'04.53392"	87°58'58.56228"	190.721m

Figure 2.1 Racine County Base Station Locations

Time Period: The Racine County Area 2 was collected between March 18th, 2010 and March 29th, 2010 with a total of three (3) flight missions. A summary of the flight information is provided in Table 2.3. Table 2.4 provides the flight mission summary. Figure 2.2 provides a graphic of the flightlines for the county collection. There were no conditions affecting flight.

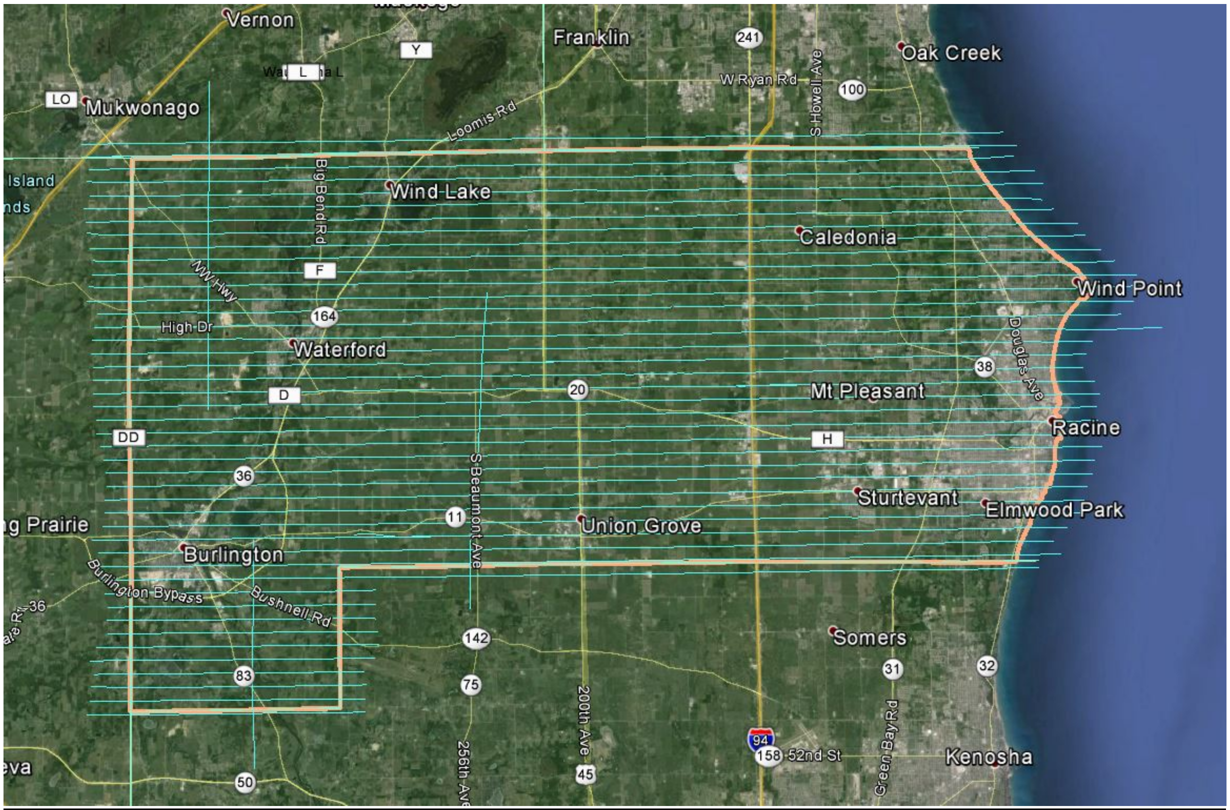
Table 2.3 Airborne LiDAR Acquisition Flight Summary

Acquisition Date, Mission, and Time	L031810A 19:22 – 22:29CDT M031810A 21:39 – 01:49CDT M031810B 03:12 –04:53CDT
Area of Acquisition	Racine County area 332 square miles
Aircrafts	Cessna C320E N3443Q; Aero Commander 500 N280MB
Planned Altitude	1,700 meters AGL
Planned Airspeed	160 knots
Planned Number of Flight Lines	L031810A 14 passes 03.18.2010 31-44 M031810A 17 passes 03.19.2010 14-30 M031810B 13 passes 03.19.2010 1-13
Flight Line Spacing	618 meters
Flight Line Coverage	960 sq. kilometers
Sidelap	55%
System PRF	70 kHz
Mirror Scan Half Angle	22 degrees
Mirror Scan Rate	32 Hz
Nominal Point Density	1.3 points per square meter per pass
Datum	NAD83
	NAVD88 via Geoid09 in Feet
Projection and Units	Universal Transverse Mercator (UTM) 16N meters

Table 2.4 Mission Flightline Summary Racine County, Wisconsin

Mission	Time of acquisition	Block flown	Lines acquired
L031810A	19:22-22:29	Area 1	Lines 31-44
M031810A	21:41-1:49	Area 2	Lines 14-30
M031810B	03:16-04:53	Area 3	Lines 1-13

(Figure 2.2 LiDAR Flight Line Layout Map– Racine County, Wisconsin)



Section 3 **LiDAR Data Processing**

ABGPS and IMU Processing

Applanix - POSGPS

Utilizing carrier phase ambiguity resolution on the fly (i.e., without initialization), the solution to sub-decimeter kinematic positioning without the operational constraint of static initialization as used in semi-kinematic or stop-and-go positioning was utilized for the airborne GPS post-processing.

The processing technique used by Applanix, Inc. for achieving the desired accuracy is Kinematic Ambiguity Resolution (KAR). KAR searches for ambiguities and uses a special method to evaluate the relative quality of each intersection (RMS). The quality indicator is used to evaluate the accuracy of the solution for each processing computation. In addition to the quality indicator, the software will compute separation plots between any two solutions, which will ultimately determine the acceptance of the airborne GPS post processing.

Inertial Data

The post-processing of inertial and aiding sensor data (i.e. airborne GPS post processed data) is to compute an optimally blended navigation solution. The Kalman filter-based aided inertial navigation algorithm generates an accurate (in the sense of least-square error) navigation solution that will retain the best characteristics of the processed input data. An example of inertial/GPS sensor blending is the following: inertial data is smooth in the short term. However, a free-inertial navigation solution has errors that grow without bound with time. A GPS navigation solution exhibits short-term noise but has errors that are bounded. This optimally blended navigation solution will retain the best features of both, i.e. the blended navigation solution has errors that are smooth and bounded.

The resultant processing generates the following data:

- Position: Latitude, Longitude, Altitude
- Velocity: North, East, and Down components
- 3-axis attitude: roll, pitch, true heading
- Acceleration: x, y, z components
- Angular rates: x, y, z components

The airborne GPS and blending of inertial and GPS post-processing were completed in multiple steps.

1. The collected data was transferred from the field data collectors to the main computer. Data was saved under the project number and separated between LiDAR mission dates. Inside each mission date, a sub-directory was created with the aircraft's tail number and an A or B suffix was attached to record which mission of the day the data is associated with. Inside the tail number sub-directory, five sub-directories were also created: EO, GPS, IMU, PROC, and RAW.

2. The aircraft raw data (IMU and GPS data combined) was run through a data extractor program. This separated the IMU and GPS data. In addition to the extraction of data, it provided the analyst the first statistics on the overall flight. The program was POSPac (POS post-processing PACkage).

3. Executing POSGPS program to derive accurate GPS positions for all flights:

   Applanix POSGPS

   The software utilized for the data collected was PosGPS, a kinematic on-the-fly (OTF) processing software package. Post processing of the data is computed from each base station (Note: only base stations within the flying area were used) in both a forward and backward direction. This provides the analyst the ability to Quality Check (QC) the post processing, since different ambiguities are determined from different base stations and also with the same data from different directions.

   The trajectory separation program is designed to display the time of week that the airborne or roving antenna traveled, and compute the differences found between processing runs. Processed data can be compared between a forward/reverse solution from one base station, a reverse solution from one base station and a forward solution from the second base station, etc. For the Applanix POSGPS processing, this is considered the final QC check for the given mission. If wrong ambiguities were found with one or both runs, the analyst would see disagreements from the trajectory plot, and re-processing would continue until an agreement was determined.

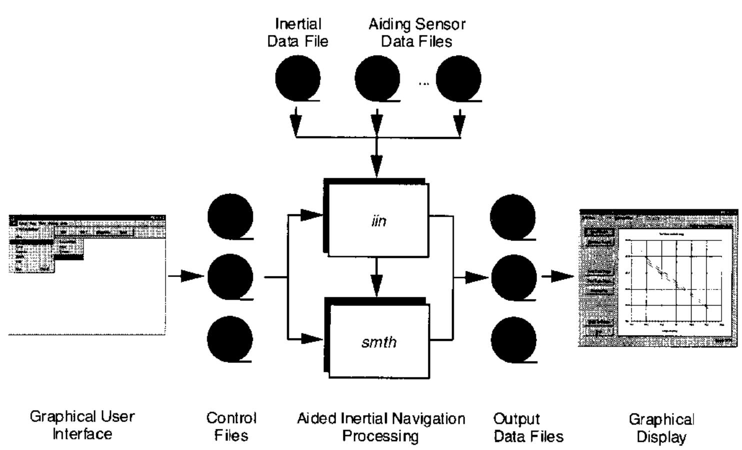
   Once the analyst accepts a forward and reverse processing solution, the trajectory plot is analyzed and the combined solution is stored in a file format acceptable for the IMU post processor.

4. When the processed trajectory (either through POSGPS) data was accepted after quality control analysis, the combined solution is stored in a file format acceptable for the IMU post processor (i.e. POSProc).

5. Execute POSProc.

   POSProc comprises a set of individual processing interface tools that execute and provide the following functions:

   This diagram shows the organization of these tools, and is a function of the POSProc processing components.



Integrated Inertial Navigation (iin) Module.

The name *iin* is a contraction of Integrated Inertial Navigation. *iin* reads inertial data and aiding data from data files specified in a processing environment file and computes the aided inertial navigation solution. The inertial data comes from a strapdown IMU. *iin* outputs the navigation data between start and end times at a data rate as specified in the environment file. *iin* also outputs

Kalman filter data for analysis of estimation error statistics and smoother data that the smoothing program *smth* uses to improve the navigation solution accuracy.

iin implements a full strapdown inertial navigator that solves Newton's equation of motion on the earth using inertial data from a strapdown IMU. The inertial navigator implements coning and sculling compensation to handle potential problems caused by vibration of the IMU.

Smoother Module (smth)

smth is a companion processing module to *iin*. *smth* is comprised of two individual functions that run in sequence. *smth* first runs the *smoother function* and then runs the *navigation correction function*.

The *smth* smoother function performs backwards-in-time processing of the forwards-in-time blended navigation solution and Kalman filter data generated by *iin* to compute smoothed error estimates. *smth* implements a modified Bryson-Frazier smoothing algorithm specifically designed for use with the *iin* Kalman filter. The resulting smoothed strapdown navigator error estimates at a given time point are the optimal estimates based on all input data before and after the given time point. In this sense, *smth* makes use of all available information in the input data. *smth* writes the smoothed error estimates and their RMS estimation errors to output data files.

The *smth* navigation correction function implements a feedforward error correction mechanism similar to that in the *iin* strapdown navigation solution using the smoothed strapdown navigation errors. s*mth* reads in the smoothed error estimates and with these, corrects the strapdown navigation data. The resulting navigation solution is called a Best Estimate of Trajectory (BET), and is the best obtainable estimate of vehicle trajectory with the available inertial and aiding sensor data.

The above mentioned modules provide the analyst the following statistics to ensure that the most optimal solution was achieved: a log of the *iin* processing, the Kalman filter Measurement Residuals, Smoothed RMS Estimation Errors, and Smoothed Sensor Errors and RMS.

LIDAR Calibration

The purpose of the LiDAR system calibration is to refine the system parameters in order for the post-processing software to produce a "point cloud" that best fits the actual ground.

For each mission, LiDAR data for at least one cross flight is acquired over the mission's acquisition site. The processed data of the cross flight is compared to the perpendicular flight lines using either the Optech proprietary software or TerraSolid's TerraMatch software to determine if any systematic errors are present. In this calibration, the data of individual flight lines are compared against each other and their systematic errors are corrected in the final processed data.

LIDAR Processing

The LAS files were then imported, verified, and parsed into manageable, tiled grids using GeoCue.

After the data has been processed and calibrated a relative accuracy assessment is performed comparing flightline to flightline for proper position between flightlines. A data density test is also performed to ensure proper coverage. Quantum Spatial uses GeoCue to create ortho images by elevation differences. The generated orthos have assigned elevation ranges that allow the technician to evaluate if the data passes the accuracy assessment and determine if additional calibration efforts are needed based on the bias trends. In Section 4, Figure 4-1 represents the elevation orthos comparing neighboring flightline vertical positions. Green indicates a difference of less than 7cm; yellow is 7cm to 14cm; orange is 14cm to 21cm; red is 21cm to 28cm and magenta is greater than 28cm.

Summary

The GPS quality for the collection was very good as represented in the plots in this section. The maximum horizontal variance for the project during collection of mission lines was 12 cm. The maximum vertical variance for the project collection was 15 cm. These values are reflected in the separation plots Figures 3.01-3.09.

Flight Log Overview

-Post Spacing – 1.3 meter
-AGL (Above Ground Level) average flying height – 1700 meters
-MSL (Mean Sea Level) average flying height – 1900 meters
-Average Ground Speed – 160 knots
-Pulse Rate – 70 kHz
-Scan Rate – 32 Hz
-Side Lap (Average) – 55%

GPS/IMU Processing Summary Plots

GPS Separation Plots

Figure 3.01 Separation Plot L031810A

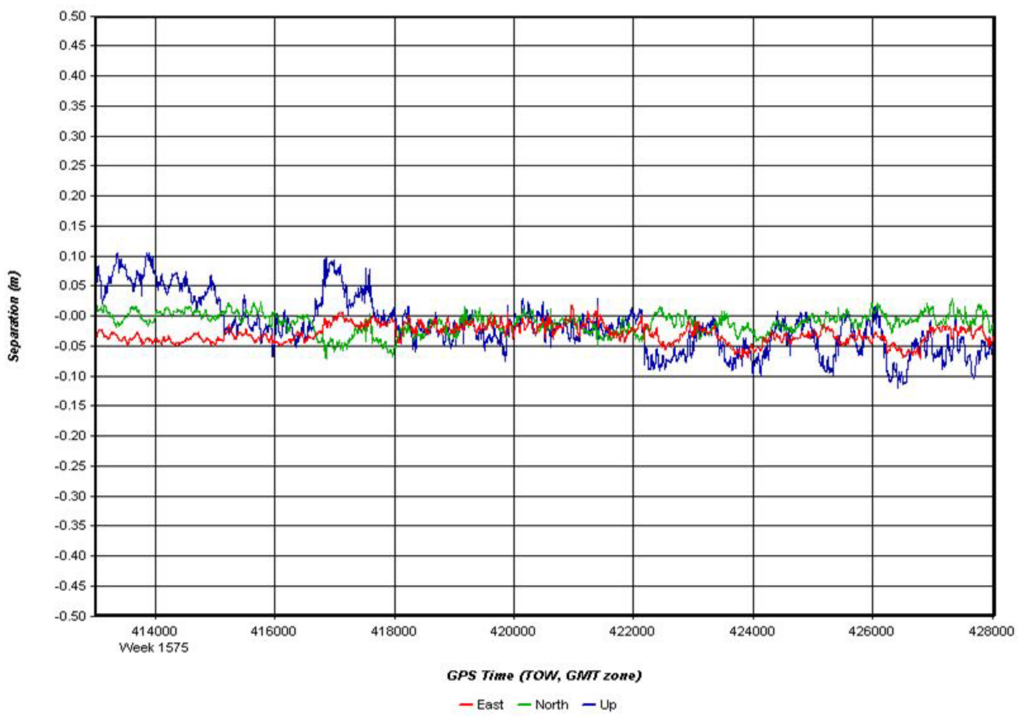


Figure 3.02 Separation Plot M031810A

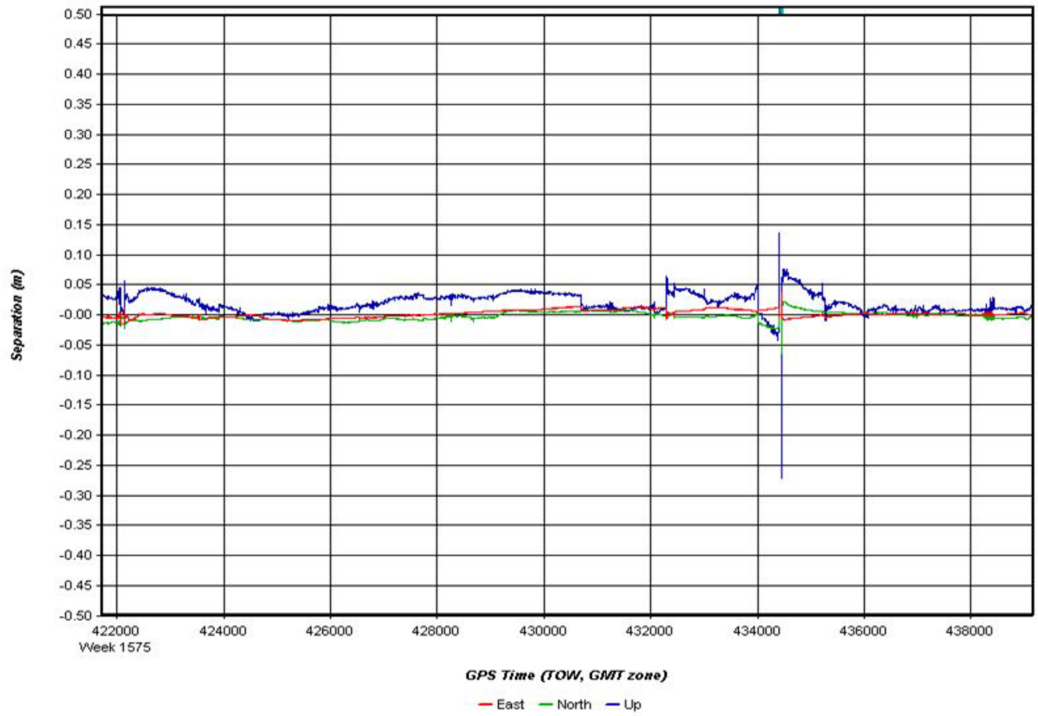
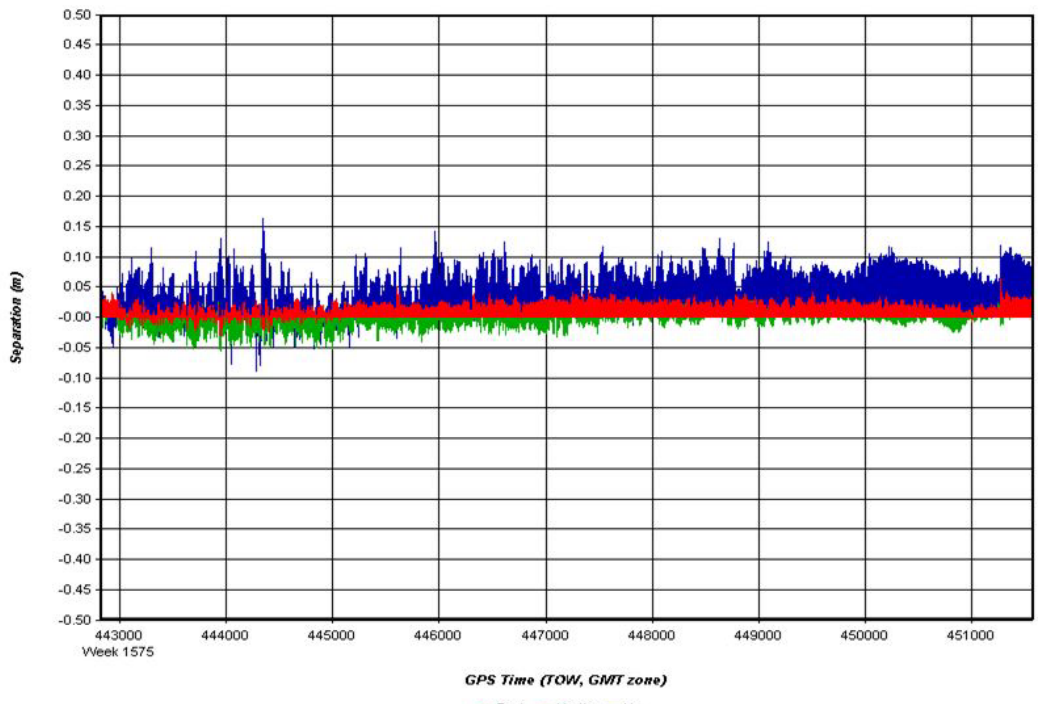


Figure 3.02 Separation Plot M031810B



GPS Altitude Plots

Figure 3.04 Altitude Plot L031810A

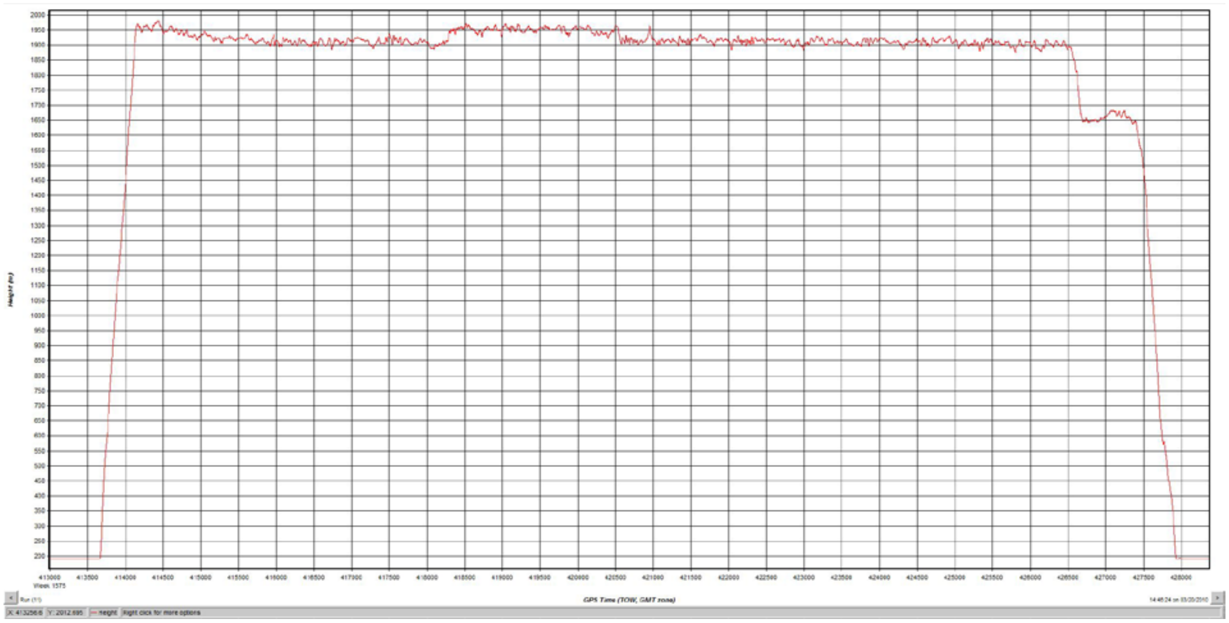


Figure 3.05 Altitude Plot M031810A

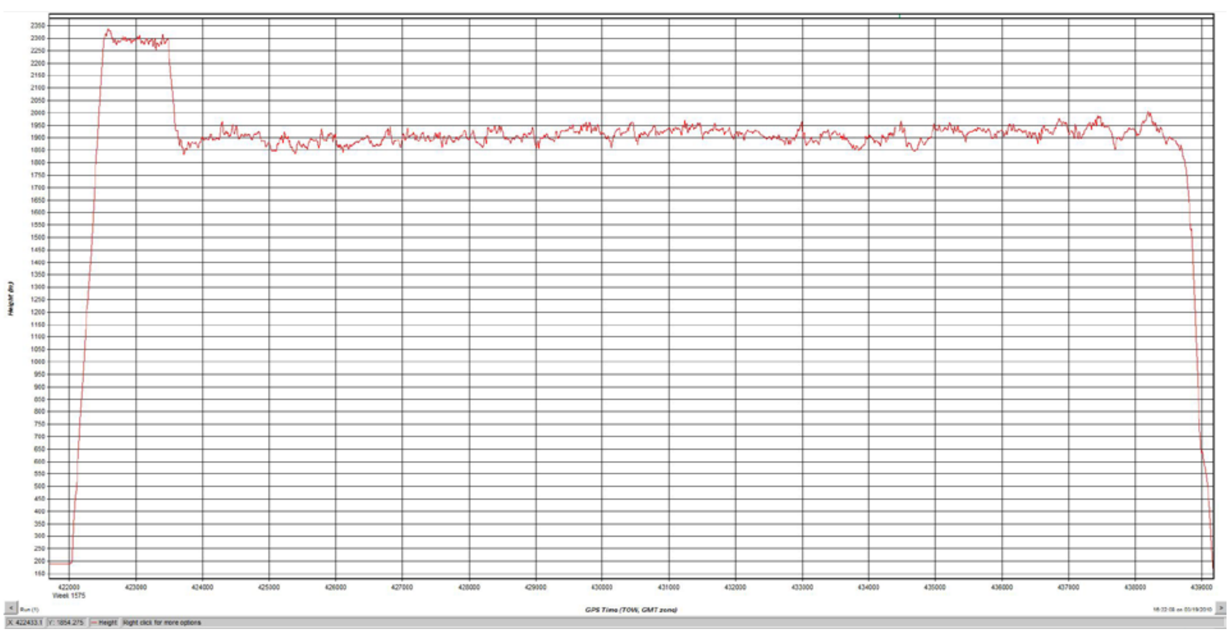
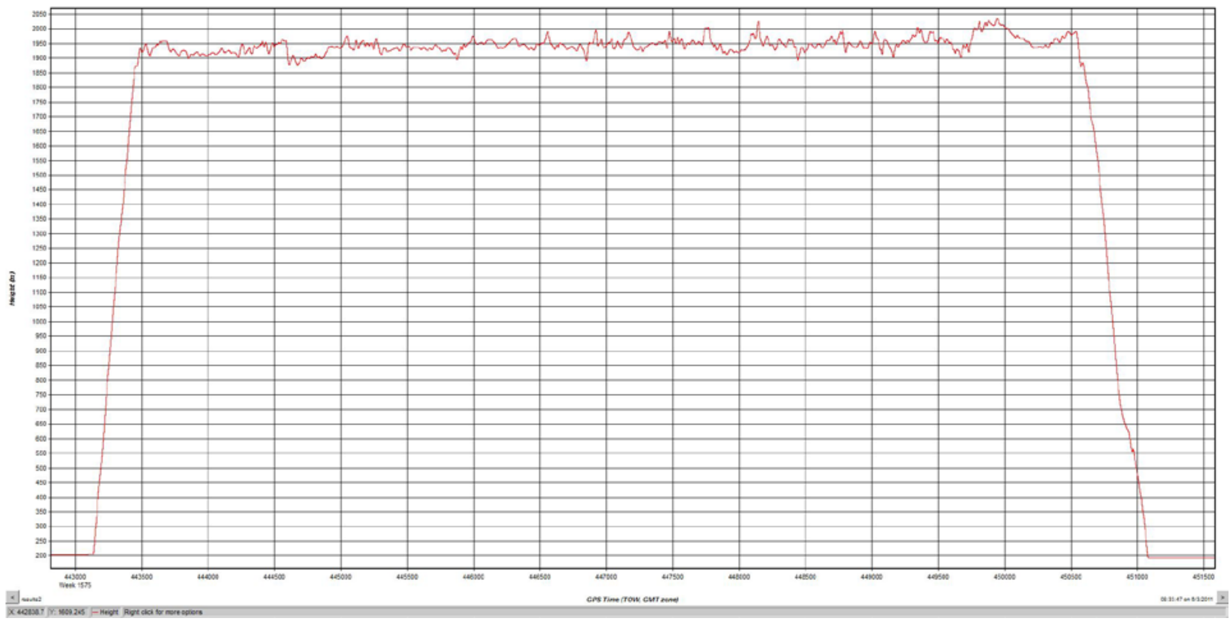


Figure 3.06 Altitude Plot M031510B



GPS PDOP Plots

Figure 3.07 PDOP Plot L031810A

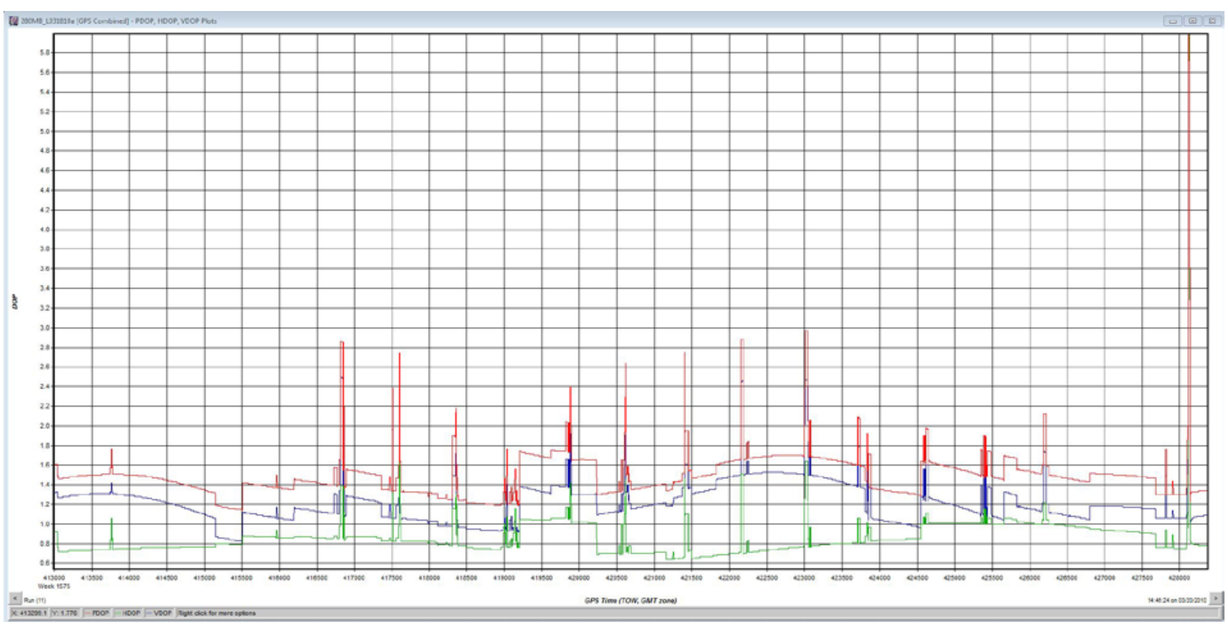


Figure 3.08 PDOP Plot M031810A

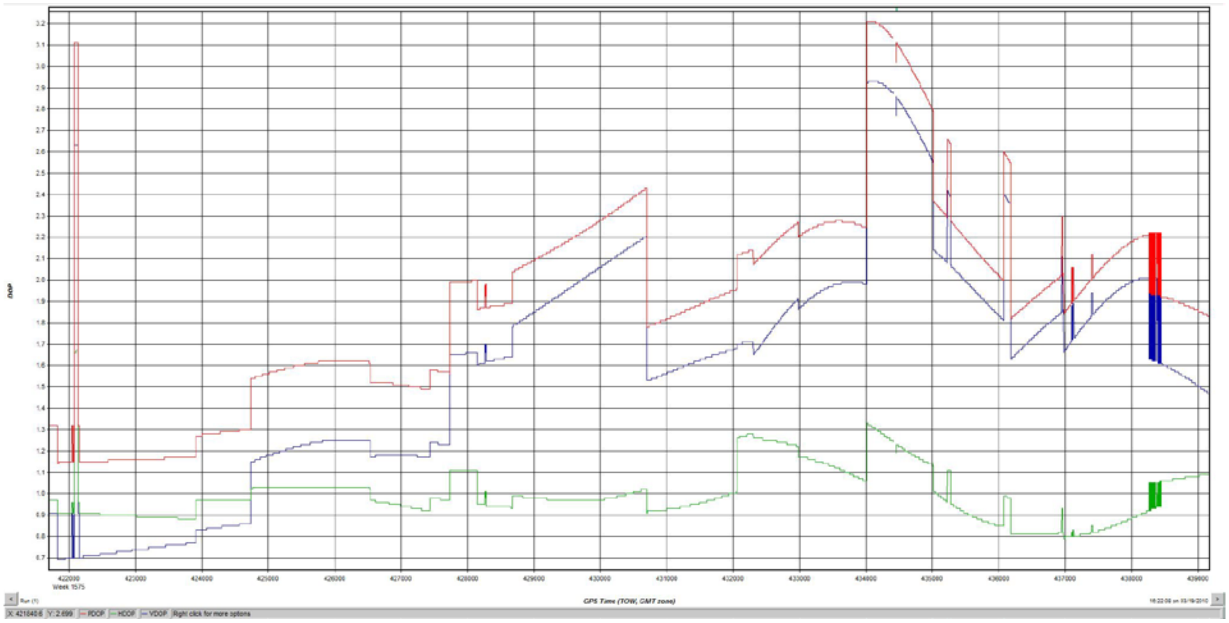
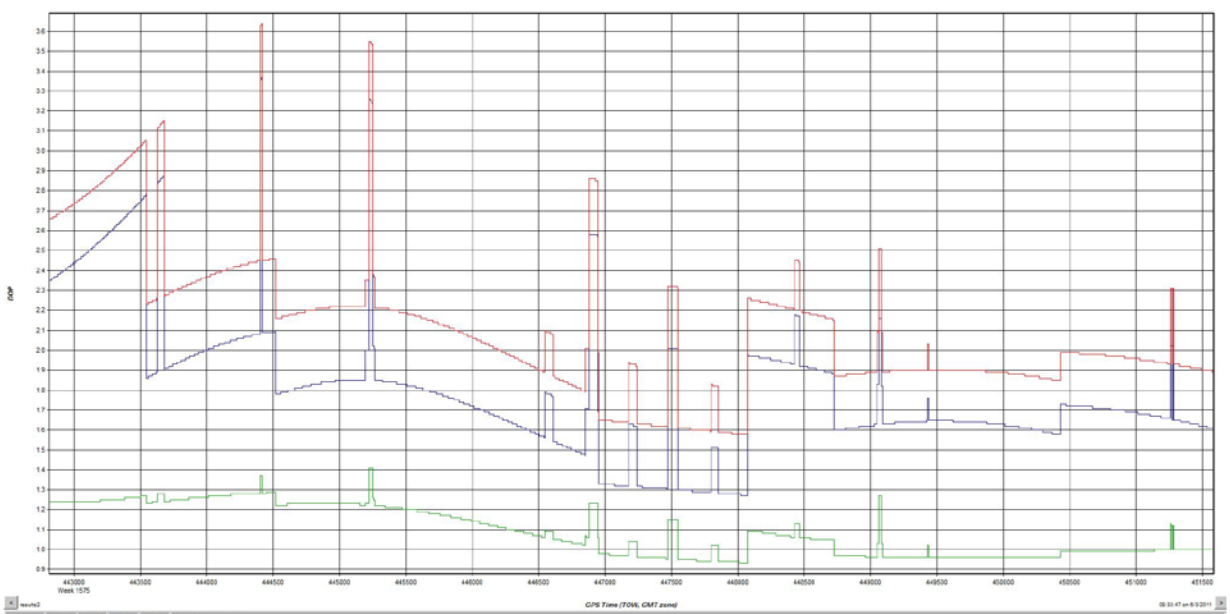


Figure 3.09 PDOP Plot M031810B



Section 4 Final Accuracy Assessment

The data was verified using the ground control data collected by Quantum Spatial. 223 points were distributed throughout the project area and the points were compared to the LIDAR data using TerraScan. TerraScan computes the vertical differences between the surveyed elevation and the LiDAR derived elevation for each point.

The Fundamental Vertical Accuracy (FVA) of the classified bare earth achieved RMSE of 0.500 ft (0.980 ft at the 95% confidence level) in the "Open Terrain" land cover category. This test consisted of 46 vertical checkpoints across Racine County.

The Supplemental Vertical Accuracy (SVA) was tested by Quantum Spatial as follows:
Hard Surface/Urban achieved RMSE of 0.500ft (0.936 ft at the 95th Percentile) using 46 points.
Short Grass achieved RMSE of 0.444ft (0.751 ft at the 95th Percentile) using 44 points.
Long Grass achieved RMSE of 0.485ft (0.977 ft at the 95th Percentile) using 45 points.
Brush achieved RMSE of 0.466ft (0748ft at the 95th Percentile) using 43 points.
Forest achieved RMSE of 0.507ft (0.862ft at the 95th Percentile) using 45 points.

The Consolidated Vertical Accuracy (CVA) results for all Land Cover Classes combined achieved RMSE of 0.481ft (0.920 ft at the 95th Percentile) using 223 Points.

Overall vertical accuracy statistics for hard surface are in Table 4-1. See accompanying Racine_Survey_points_with_Formulas(1).xls for additional information.

Figure 4.1 represents elevation orthos that compare neighboring flightline vertical positions. Green indicates a difference of less than 7cm; yellow is 7cm to 14cm; orange is 14cm; to 21cm; red is 21cm to 28cm; magenta is greater than 28cm.

Figure 4.1 Racine County - DZ Raster Image

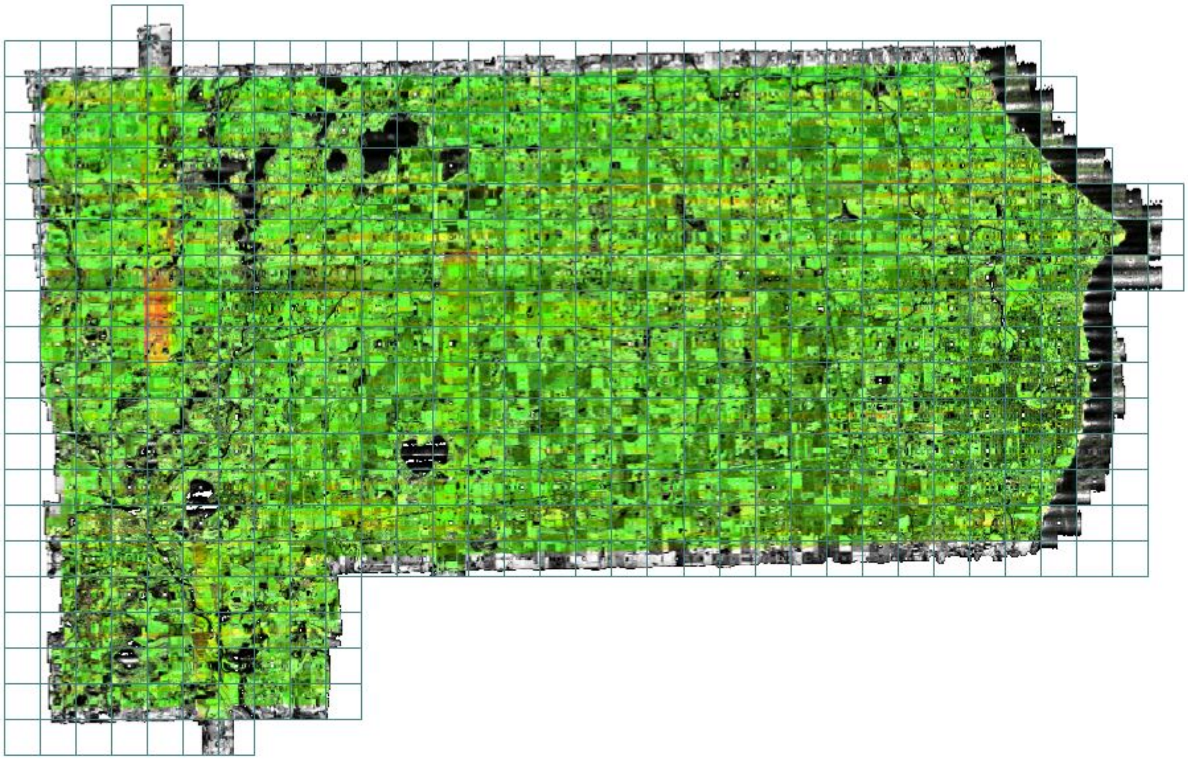


Table 4-1 Overall Vertical Accuracy Statistics

Point	Surveyed Elev.	LiDAR Elev.	Difference	Land Category
4	770.317	769.70	-0.617	Hard Surface
10	745.497	744.83	-0.667	Hard Surface
14	750.579	750.38	-0.199	Hard Surface
20	822.262	822.35	0.088	Hard Surface
25	742.63	742.64	0.01	Hard Surface
30	769.195	769.00	-0.195	Hard Surface
35	727.236	727.06	-0.176	Hard Surface
40	826.888	826.03	-0.858	Hard Surface
45	782.167	781.02	-1.147	Hard Surface
50	794.391	793.78	-0.611	Hard Surface
55	799.998	799.72	-0.278	Hard Surface
58	830.274	829.69	-0.584	Hard Surface
65	752.351	752.42	0.069	Hard Surface
75	688.253	688.34	0.087	Hard Surface
77	681.314	680.92	-0.394	Hard Surface
81	782.193	782.18	-0.013	Hard Surface
83	777.915	777.24	-0.675	Hard Surface
88	804.273	804.27	-0.003	Hard Surface
95	826.252	826.27	0.018	Hard Surface
101	808.381	807.92	-0.461	Hard Surface
501	795.966	795.82	-0.146	Hard Surface
502	814.099	814.08	-0.019	Hard Surface
503	776.107	775.01	-1.097	Hard Surface
504	810.104	809.41	-0.694	Hard Surface
505	829.955	829.32	-0.635	Hard Surface
506	780.652	780.12	-0.532	Hard Surface
507	668.519	667.58	-0.939	Hard Surface
508	720.005	719.71	-0.295	Hard Surface
509	682.095	681.59	-0.505	Hard Surface
510	645.202	645.17	-0.032	Hard Surface
511	655.845	655.34	-0.505	Hard Surface
512	630.586	630.23	-0.356	Hard Surface
513	586.538	586.5	-0.038	Hard Surface
514	696.131	696.01	-0.121	Hard Surface
515	692.263	692.19	-0.073	Hard Surface
516	683.175	683.22	0.045	Hard Surface
517	742.466	742.47	0.004	Hard Surface
518	741.199	741.15	-0.049	Hard Surface
519	719.381	718.57	-0.811	Hard Surface
520	791.721	791.06	-0.661	Hard Surface
521	808.597	808.19	-0.407	Hard Surface
522	814.68	813.84	-0.84	Hard Surface
523	821.976	821.05	-0.926	Hard Surface
524	781.951	781.95	-0.001	Hard Surface
525	821.347	821.24	-0.107	Hard Surface
526	772.532	772.40	-0.132	Hard Surface

Average Dz	-0.358
Root mean square (RMS)	0.500
Standard Deviation	0.353

Section 5 **Final Processing Requirements**

The Racine County project has been completed under two contracts, and thus to two project requirements. The Southeast Wisconsin Regional Planning Commission (SEWRPC) funded the LiDAR acquisition for the entire county. The county was the divided into Project Area No. 1 and Project Area No. 2 for processing. See Figure 5.1 for a graphical representation of these project areas. However, only Project Area No. 1 was funded for processing to obtain the bare earth data and derived products (DTM and Contours). FEMA Region V funded the processing of the Project Area No. 2 to the SEWRPC specifications, as well as to convert the entire county to FEMA specifications. See Table 5.1for project specifications.

STARR deliverables include the county-wide point cloud data, county-wide bare earth LAS, and county wide DTM/DEM and contours in both deliverable formats.

The initial processing to the point cloud deliverable was done in WGS84. From that point the processing steps were parallel for the two datasets such that transformations/projections were accomplished only once on each dataset to maintain the positional integrity of the data.

Figure 5.1 Project Areas

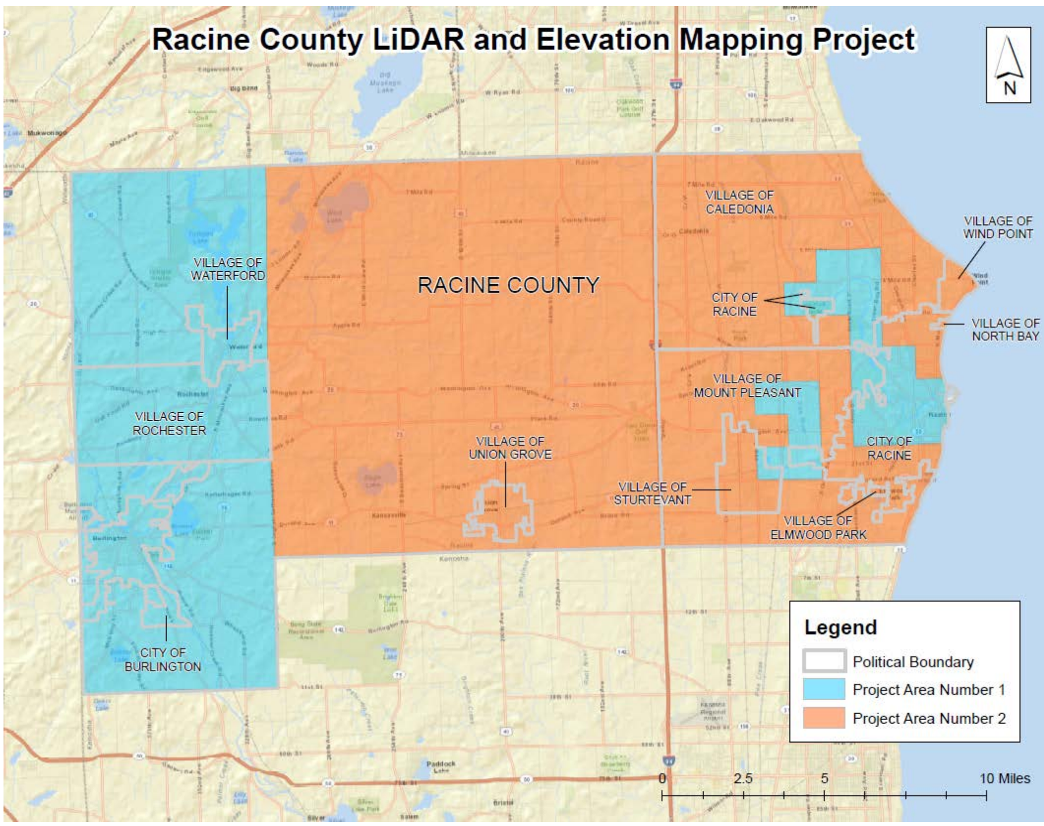


Table 5.1 Project Specifications

	SEWRPC	FEMA
Horizontal Datum	NAD27	NAD83
Vertical Datum	NGVD29	NAVD88
Projection	Wisconsin State Plane, South Zone	UTM
Units	US Survey Feet	US Survey Feet
LiDAR Deliverable	ASCII comma delimited, LAS	LAS
DTM	3-dimensional MicroStation DGN	ESRI DEM – 5' posting
Contours	3-dimensional MicroStation DGN	ESRI Shapefile format

Appendix A: Condensed Flight Logs

L031810A

```
           Flight Log
------------------------------
Project Number: 1100319
S/N           : 07SEN201
Operator      : TOM
Pilot(s)      : JOSEY
Aircraft      : N280MB
Airport       : KSBM
Mission       : L031810A
Wheels Up     : 18:52
Flight Length :
HOBBS Start   :
HOBBS End     :

           Weather
------------------------------
Date          : March 18, 2010
Julian Day    : 077
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : LOTS
           Statistics
------------------------------
Laser Time    : 02:13:23
```

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	HDG	Plan File
19:19:46.3	19:20:21.3	44	1923	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
19:21:05	19:21:36.9	44	1915	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
19:22:10	19:30:55.803	44	1908	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
19:36:14.504	19:45:06.206	43	1922	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
19:48:23.707	19:57:16.91	42	1903	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
20:01:05.411	20:09:59.313	41	1905	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
20:13:34.714	20:22:44.117	40	1945	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
20:26:51.418	20:35:43.721	39	1963	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
20:39:09.022	20:48:25.224	38	1961	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
20:52:33.626	21:01:50.228	37	1905	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:05:17.829	21:14:52.632	36	1910	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
21:18:53.734	21:28:26.737	35	1910	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:31:58.938	21:41:38.841	34	1905	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
21:45:29.642	21:55:17.745	33	1910	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:58:48.446	22:08:33.649	32	1891	70	32.00	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
22:12:47.751	22:22:26.254	31	1880	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
22:25:53.455	22:29:03.356	31	1885	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln

M031810A

```
            Flight Log
----------------------------------
Project Number: 1100319
S/N           : Racine
Operator      : Jim
Pilot(s)      : Nick
Aircraft      : N3443Q
Airport       : KSBM
Mission       : M031810A
Wheels Up     : ???
Flight Length :
HOBBS Start   : 21:08
HOBBS End     :

            Weather
----------------------------------
Date          : March 18, 2010
Julian Day    : 077
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : 29.81
            Statistics
----------------------------------
Laser Time    : 02:29:25
```

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	HDG	Plan File
21:39:16.615	21:39:37.114	15	1980	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:40:04.614	21:40:31.613	15	1891	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:40:59.613	21:50:42.601	15	1891	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:40:59.613	21:50:43.101	15	1891	70	32.00	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
21:54:59.596	22:04:24.084	22	1845	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
22:08:06.08	22:17:33.569	16	1883	70	31.90	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
22:21:29.064	22:30:48.053	23	1865	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
22:34:33.548	22:43:46.037	17	1883	70	31.90	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
22:47:08.033	22:56:32.022	24	1863	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
22:58:37.519	23:07:59.008	18	1904	70	31.90	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
23:11:13.504	23:20:37.493	25	1922	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
23:23:52.489	23:33:07.478	19	1935	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
23:36:35.473	23:45:44.462	26	1933	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
23:49:44.957	23:59:06.945	20	1902	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
00:02:24.441	00:11:45.93	27	1886	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:15:38.925	00:24:47.913	21	1926	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
00:15:38.925	00:24:48.913	21	1926	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
00:15:38.925	00:24:49.913	21	1926	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
00:28:11.909	00:37:47.897	28	1890	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:42:09.392	00:51:44.88	30	1923	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
00:56:20.374	01:05:05.863	29	1904	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:10.362	29	1926	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:14.862	29	1927	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:19.362	29	1928	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:20.862	29	1928	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:31.861	29	1929	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:40.361	29	1928	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:49.361	29	1923	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:06:56.861	29	1911	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:07:45.36	29	1928	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:07:46.86	29	1927	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:08:24.359	29	1949	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:08:25.359	29	1950	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:08:26.859	29	1950	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:08:30.859	29	1950	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:08:37.359	29	1951	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:09:17.358	29	1944	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:09:26.858	29	1950	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:09:28.358	29	1950	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:09:29.358	29	1949	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
00:56:20.374	01:10:45.356	29	1932	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln

M031810A (Cont)

```
          Flight Log
------------------------------
Project Number: 1100319
S/N           : Racine
Operator      : Jim
Pilot(s)      : Nick
Aircraft      : N3443Q
Airport       : KRAC
Mission       : M031810A
Wheels Up     : ???
Flight Length :
HOBBS Start   :
HOBBS End     : 2:07

          Weather
------------------------------
Date          : March 18, 2010
Julian Day    : 077
Temperature   : ???
Visibility    : ???
Clouds        : ???
Precipitation : ???
Wind Dir      : ???
Wind Speed    : ???
Pressure      : ???
          Statistics
------------------------------
Laser Time    : 00:14:25
```

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	HDG	Plan File
01:16:57.848	01:19:55.845	30	1936	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
01:23:10.341	01:24:17.339	27	1921	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
01:25:25.838	01:26:00.837	25	1923	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
01:33:40.328	01:40:30.819	14	1909	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
01:46:46.312	01:49:55.808	14	1888	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln

M031810B

Flight Log

Project Number: 1100319
S/N : Racine
Operator : Jim
Pilot(s) : Nick
Aircraft : N3443Q
Airport : KBUU
Mission : M031810B
Wheels Up : ???
Flight Length :
HOBBS Start : 03:00
HOBBS End :

Weather

Date : March 18, 2010
Julian Day : 077
Temperature : ???
Visibility : ???
Clouds : ???
Precipitation : ???
Wind Dir : ???
Wind Speed : ???
Pressure : ???

Statistics

Laser Time : 00:53:21

START	STOP	LINE#	ALT	PRF	FREQ	ANGLE	MP	DIV	RC	HDG	Plan File
03:11:59.148	03:12:25.147	13	1921	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
03:12:32.147	03:12:53.147	13	1927	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
03:16:09.643	03:25:16.132	13	1921	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
03:29:32.627	03:38:17.116	12	1930	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
03:42:25.111	03:51:27.1	11	1917	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
03:59:00.091	04:01:32.588	6	1944	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
04:04:27.085	04:06:54.582	1	1934	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
04:09:18.579	04:11:48.576	7	1931	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
04:14:20.073	04:16:48.07	2	1952	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
04:19:21.067	04:21:49.564	8	1948	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
04:24:43.56	04:27:06.557	3	1926	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
04:29:41.554	04:32:12.051	9	1942	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
04:34:55.048	04:37:20.045	4	1938	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
04:40:06.042	04:42:30.539	10	1931	70	32.40	22.00	NAR	OFF	OFF	270.00	racine_fixline.pln
04:44:56.536	04:47:24.033	5	1951	70	32.40	22.00	NAR	OFF	OFF	90.00	racine_fixline.pln
04:51:52.028	04:53:42.525	10	1916	70	32.40	22.00	NAR	OFF	OFF	90.00	racine fixline.pln

Appendix B: Original Flight Logs

L031810A

LIDAR FLIGHT LOG

ALTM | TPL

MISSION: L031810A | DATE: 3-18-10 THURS.

PILOT: JOSEY | OPERATOR: Tom | AIRCRAFT: 280MB

PROJECT NUMBER	LINE NO.	& Hdg	GND SPEED (KTS)	SCAN FREQ	SCAN ANGLE	PRF	ALT (m)	CDT TIME GPS START	STOP	Tranzpak Drive	REMARKS
1100319		2	TESTS	19:19	→	19:21		1:30	2:24	008	FERRY: SBM → SITE .9
	44	E	±156	32	22°	70	1700	19:22	19:30		SOME ICE ON LAKES/PONDS
	43	W						19:36	19:45		
	42	E						19:48	19:57		
	41	W	154-161					20:01	20:10		
	40	E	153-160					20:13	20:22		ATC: 6.5 ASSIGNED 85m Hz E.
	39	W						20:24	20:35		
	38	E						20:39	20:48		
	37	W						20:52	21:01		
	36	E						21:05	21:14		
	35	W						21:10	21:28		
	34	E						21:31	21:41		
	33	W						21:45	21:55		
	32	E						21:58	22:08		
	31	W						22:12	22:22		
XFLT	31	N						22:25	22:29		
								5:30	6:04		FERRY: SITE → SBM .6

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START:	STOP:
⊘ 1100319	44	14	30	3.1	1.5			
○						WX		
○								

NOTES:
SOME MINOR FLOODING IN A FEW LOW AREAS IN SOME FIELDS
NO SNOW... GOOD CALL ON BROWN.

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE. 920-467-2655 FAX: 920-457-1451 E-Mail: amephoto@aerometric.com

15 & N

Mar 18 10 06:16p Aero-Metric Hangar 920-467-1220 p.1

M031810A

LIDAR FLIGHT LOG

ALTM JS1

MISSION: M031810A DATE: 3-18-10 THUR

PILOT: NICK OPERATOR: JIM AIRCRAFT: N 3443Q

PROJECT NUMBER	LINE NO.	& Hdg	GND SPEED (KTS)	SCAN FREQ	SCAN ANGLE	PRF	ALT (m)	TIME START	TIME STOP	Tranzpak Drive	REMARKS
1100319								21:08	21:41		FERRY'S SBM → SITE ALL TIMES GMT
RACINE	2 TEST							21:39	21:40	0181	
	15	270	155	32.0	22	70	1700	21:41	21:50		
	22	90	160	32.4				21:55	22:04		
	16	270	155	31.9				22:08	22:17		
	23	90	160	32.4				22:21	22:30		
	17	270	155	31.9				22:34	22:43		
	24	90	160	32.4				22:47	22:56		
	18	270	155	31.9				22:58	23:08		
	25	90	160	32.4				23:11	23:20		
	19	270						23:23	23:33		
10	26	90						23:36	23:45		
	20	270						23:49	23:59		
	27	90						00:02	00:11		
	21	270						00:15	00:24		
	28	90						00:28	00:37		
15	30	270						00:42	00:51		
16	29	90						00:56	01:10		LASER WOULD NOT SHUT OFF
											PWR DOWN – LOST APC PWR
	CROSS	N						01:16	01:19		→ JS2

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START:	STOP:	NOTES:
⊗ 1100319	44	15/31	13	4.1	1.0		21:08	02:32	
○			0	1.7	.7	WX HIGH SCUZZY CIRRUS			
○				5.8	1.8				

(7.6)

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M031810A

Mar 19 10 12:54a Aero-Metric Hangar 920-467-1220 p.2

LIDAR FLIGHT LOG

ALTM JS2

MISSION: M031810A DATE: 3-18-10 THUR

PILOT: NICK OPERATOR: JIM AIRCRAFT: N3443Q

PROJECT NUMBER	LINE NO.	& Hdg	GND SPEED (KTS)	SCAN FREQ	SCAN ANGLE	PRF	ALT (m)	TIME START	TIME STOP	Tranzpak Drive	REMARKS	
1100319	27	90	160	32.4	22	70	1700	01:23	01:24	0181	GAP AREA	
RACINE	25	90						01:25	01:26		GAP AREA	
17	14	270						01:33	01:40		PARTIAL – OFF LINE	
	14	90						01:46	01:49		LINE COMPLETE	
									02:07		FERRY: SITE → RAC	.3
								2:15	02:32		FERRY: RAC → BOU	
											→ JS3 NEW MISSION	.2

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START:	STOP:	NOTES:
○									
○						WX			
○									

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M031810B

Mar 19 10 12:53a Aero-Metric Hangar 920-467-1220 p.1

LIDAR FLIGHT LOG

ALTM J53

MISSION: M031810B DATE: 3-18-10 THUR

PILOT: NICK OPERATOR: JIM AIRCRAFT: N3443Q

PROJECT NUMBER	LINE NO. & Hdg		GND SPEED (KTS)	SCAN FREQ	SCAN ANGLE	PRF	ALT (m)	TIME START	TIME STOP	Tranzpak Drive	REMARKS	
110031.9								03:00	03:12		FERRY: BUW → SITE	.2
RACINE	2 TEST							03:12	03:12			
	13	90	160	32.4	22	70	1700	03:16	03:25	0181		
	12	270						03:29	03:38			
	11	90						03:42	03:51			
	6	270						03:59	04:01			
	1	90						04:04	04:06			
	7	270						04:09	04:11			
	2	90						04:14	04:16			
	8	270						04:19	04:21			
	3	90						04:24	04:27			
	9	270						04:29	04:32			
	4	90						04:34	04:37			
	10	270						04:40	04:42			
	5	90						04:44	04:47			
	CROSS	N						04:51	04:53			
									05:25		FERRY: SITE → SBM	.5

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START:	STOP:	NOTES:
							03:00		
						WK			

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