Kane County, UT Lidar
USGS TO# G20AC00110

Lidar Report

October, 2020

EXECUTIVE SUMMARY

The Utah Automated Geographic Reference Center (AGRC) contracted with The Sanborn Map Company, Inc. (Sanborn) to provide remote sensing services for Kane County, UT in the form of lidar. Utilizing a multi-return system, Light Detection and Ranging (Lidar) detects 3-dimensional positions and attributes to form a point cloud. The high accuracy airborne system is integrated with both Global Navigation Satellite System (GNSS) and an Inertial Measure Unit (IMU) for accurate position and orientation. Acquisition of the project area's ~6,115mi² was completed on November 16th, 2019.

The Leica CityMapper and TerrainMapper were used to collect data for the aerial survey campaign. The sensor is attached to the aircraft's underside and emits rapid laser pulses that are used to calculate ranges between the aircraft and subsequent terrain below. The Airborne Lidar System (ALS) is boresighted by completing multiple passes over a known ground surface before the project acquisition. During data processing, the system calibration parameters are updated and used during post-processing of the lidar point cloud.

Differential GNSS unit in aircraft sampled positions at 2Hz or higher frequency. Lidar data was only acquired when GNSS PDOP is ≤4 and at least 6 satellites are in view. Collection conditions were for leaf-off vegetation. The atmosphere was free of clouds and fog between the aircraft and ground. The ground was free of snow and extensive flooding or any other type of inundation

The contents of this report summarize the methods used to establish the base station coordinates, perform the lidar data acquisition and processing as well as the results of these methods.

CONTENTS

1.0 INTRODUCTION

This document contains the technical write-up of the lidar campaign, including system calibration techniques, and the collection and processing of the lidar data.

1.1 Contact Information

Questions regarding the technical aspects of this report should be addressed to:

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1.2 Purpose of Lidar Acquisition

The objective of this project is to collect accurate measurements of the bare-earth surface as well as above ground features to be provided as geometric inputs for surface and/or change modeling as is relates survey assessments.

1.3 Project Location

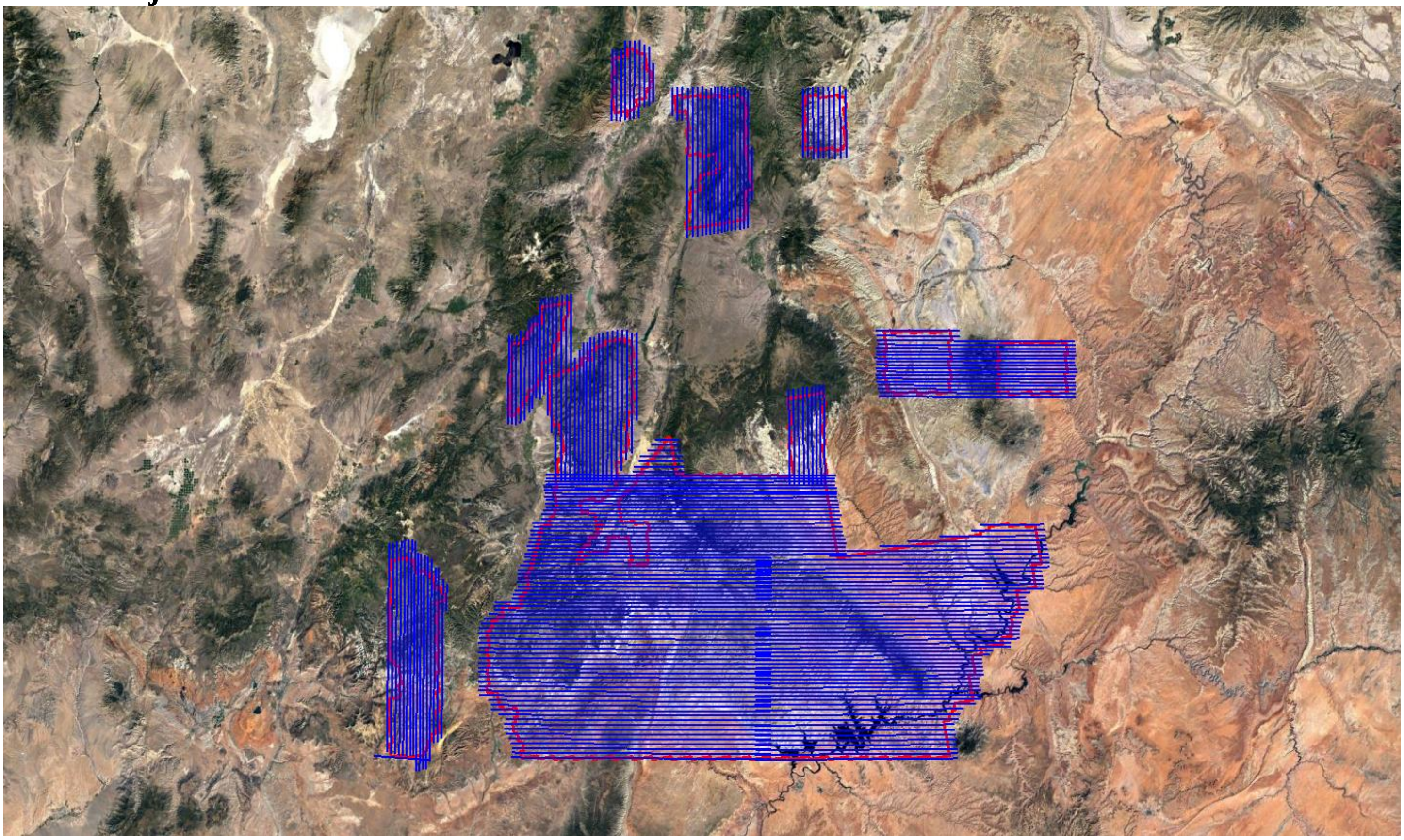


Figure 1: DPA and Trajectories As-Flown

2.0 ACQUISITION

2.1 Introduction

This section outlines the lidar system, flight reporting and data acquisition methodology used during the collection of the Kane County, UT lidar campaign. Although Sanborn conducts all lidar missions with the same rigorous and strict procedures and processes, all lidar collections are unique.

2.2 Acquisition Parameters

Sanborn specifically defined the collection parameters to accomplish the desired project specifications. **Table 1** shows the planned acquisition parameters utilized for this aerial survey with the sensor(s) installed.

Planned Acquisition Parameters		
Sensor	Leica CityMapper	Leica TerrainMapper
Aircraft	N345DP – CESSNA T206H	N603ET – CESSNA TU206F
Flying Height (AGL) (m)	3680	3680
Air Speed (kts)	150	150
Field of View (degrees)	40	40
Overlap (%)	20	20
Pulse Rate (kHz)	613.6	613.6
Scan Rate (Hz)	80.4	80.4
Laser Footprint (m)	0.86	0.86
Multi-Pulse	Gateless	Gateless
Point Spacing (m)	0.68	0.68
Point Density (pls/m²)	2.2	2.2
Swath Width (m)	2328	2328

Table 1: Lidar Acquisition Parameters

2.3 Field Work Procedures

Sanborn's standard procedure before every mission is to perform pre-flight checks to ensure correct operation of all systems. All cables were checked and the sensor head glass was cleaned. A three minute static session was conducted on the ground with the engines running prior to take-off in order to establish fine-alignment of the IMU and to resolve GNSS ambiguities.

The project acquisition consisted of thirty-one (31) mission(s). During the data collection, the operator recorded information on log sheets which includes weather conditions, lidar operation parameters, flight line statistics and PDOP.

Preliminary data processing was performed in the field immediately following the missions for quality control of GNSS data and to ensure sufficient coverage of the project AOI. Any problematic data could then be re-flown immediately as required. Final data processing was completed in the Colorado Springs, CO office. **Table 2** below shows the flight acquisition metrics for the entire collection. **Table 3** contains the base station names and locations in operation during acquisition. Base station coordinates are provided in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

Date	Sensor	Serial #	Tail #	MissionID	PDOP	Start (UTC)	End (UTC)
10/11/2019	Leica TerrainMapper	TM91520	N603ET	20191011A	1.4	19:52:51	23:55:41
10/12/2019	Leica TerrainMapper	TM91520	N603ET	20191012A	1.5	17:42:30	22:32:36
10/13/2019	Leica TerrainMapper	TM91520	N603ET	20191013A	1.5	16:34:30	18:27:03
10/14/2019	Leica TerrainMapper	TM91520	N603ET	20191014A	1.5	14:41:27	19:20:46
10/15/2019	Leica TerrainMapper	TM91520	N603ET	20191015A	1.4	14:33:51	18:51:13
10/15/2019	Leica TerrainMapper	TM91520	N603ET	20191015B	1.4	22:05:48	0:50:54
10/16/2019	Leica TerrainMapper	TM91520	N603ET	20191016A	1.4	16:53:09	20:24:55
10/16/2019	Leica TerrainMapper	TM91520	N603ET	20191016B	1.5	20:57:51	23:12:52
10/19/2019	Leica TerrainMapper	TM91520	N603ET	20191019A	1.5	18:20:24	20:10:53
10/20/2019	Leica TerrainMapper	TM91520	N603ET	20191020A	1.5	16:09:51	17:42:12
10/28/2019	Leica CityMapper	CM95338	N345DP	20191028A	1.5	13:57:00	17:19:53
10/28/2019	Leica CityMapper	CM95338	N345DP	20191028B	1.4	18:23:00	20:09:27
11/3/2019	Leica TerrainMapper	TM91520	N603ET	20191103A	1.4	17:36:48	20:27:24
11/4/2019	Leica TerrainMapper	TM91520	N603ET	20191104A	1.4	17:34:18	21:14:41
11/5/2019	Leica TerrainMapper	TM91520	N603ET	20191105A	1.5	19:26:39	0:24:28
11/7/2019	Leica TerrainMapper	TM91520	N603ET	20191107A	1.5	14:58:57	19:57:26
11/8/2019	Leica TerrainMapper	TM91520	N603ET	20191108A	1.6	18:08:12	22:45:25
11/9/2019	Leica TerrainMapper	TM91520	N603ET	20191109A	1.7	17:45:15	21:40:14
11/10/2019	Leica TerrainMapper	TM91520	N603ET	20191110A	1.5	13:58:27	17:21:24
11/10/2019	Leica TerrainMapper	TM91520	N603ET	20191110B	1.5	18:22:00	22:51:34
11/11/2019	Leica TerrainMapper	TM91520	N603ET	20191111A	1.6	14:42:45	19:12:02
11/11/2019	Leica TerrainMapper	TM91520	N603ET	20191111B	1.4	20:14:36	22:58:22
11/11/2019	Leica TerrainMapper	TM91520	N603ET	20191111C	1.8	0:23:00	3:46:53
11/12/2019	Leica TerrainMapper	TM91520	N603ET	20191112A	1.6	14:18:36	19:35:12
11/12/2019	Leica TerrainMapper	TM91520	N603ET	20191112B	1.6	20:49:39	0:51:22
11/13/2019	Leica TerrainMapper	TM91520	N603ET	20191113A	1.4	16:04:27	20:56:38
11/13/2019	Leica TerrainMapper	TM91520	N603ET	20191113B	1.7	21:38:45	0:01:14
11/14/2019	Leica TerrainMapper	TM91520	N603ET	20191114A	1.7	14:14:21	17:33:43
11/14/2019	Leica TerrainMapper	TM91520	N603ET	20191114B	1.7	17:34:48	19:35:55
11/14/2019	Leica TerrainMapper	TM91520	N603ET	20191114C	1.6	20:23:03	1:15:36
11/16/2019	Leica TerrainMapper	TM91520	N603ET	20191116A	1.7	15:02:42	19:37:38

Table 2: Collection Date Time by Mission

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
B 30	NGS	JN0194	38 26 48.08808	111 48 31.08428	2501.172
BRYCE	NGS	HO0523	37 42 14.14457	112 09 13.83292	2308.803
FAA KNB A	NGS	AA3679	37 00 36.08164	112 31 51.87173	1452.751
FRED	CORS	AI8805	36 59 17.97840	112 29 57.13534	1530.645
HC 2	NGS	DN6719	37 27 51.25338	110 42 53.06979	1117.939
K 112	NGS	JN0110	38 24 44.94404	110 41 40.33888	1329.100
P009	CORS	DI2242	38 28 47.73265	112 13 21.72565	1762.281
PGA ARP	NGS	GP0075	36 55 35.09162	111 26 55.61832	1272.950
RIF B	NGS	DI2114	38 44 42.12754	112 05 42.34955	1590.462
U19 D	NGS	DK4060	38 57 46.12499	112 21 24.55858	1498.133
U52 A	NGS	DI1891	38 13 54.91577	112 40 34.14120	1752.431
U55 A	NGS	DI1890	37 50 43.52224	112 23 36.42189	2034.394

Table 3: GNSS Reference Station Coordinates

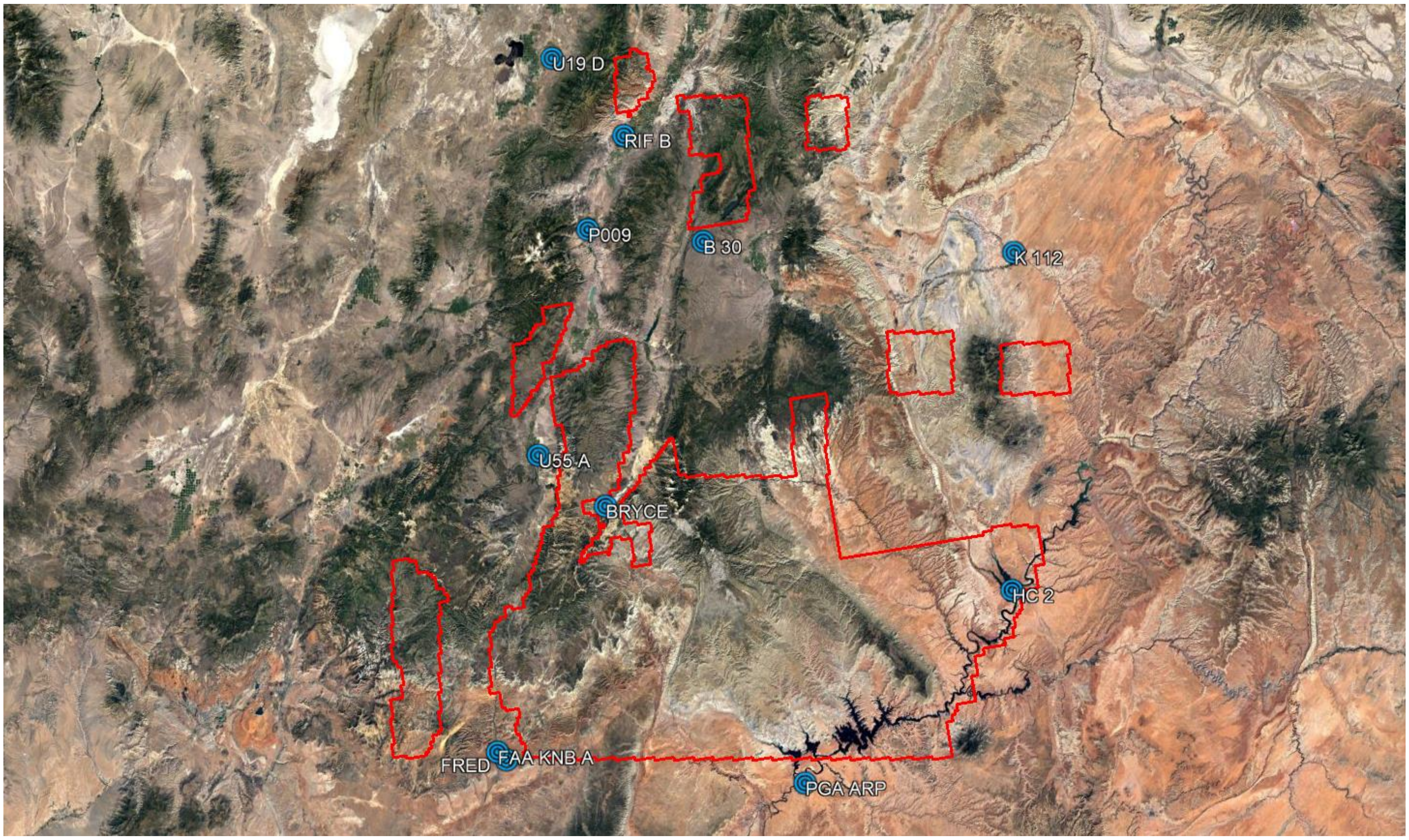


Figure 2: GNSS Reference Stations

3.0 PROCESSING

3.1 Introduction

The GNSS/IMU data was post-processed using Waypoint Inertial Explorer software to create Smoothed Best Estimate Trajectory (SBET) file(s). The SBET was then combined with the laser range measurements in Leica HxMap software to produce the 3-dimensional coordinates resulting in an accurate set of Raw Point Cloud (RPC) mass points. These raw swath (*.las) files are output in WGS84, UTM, Ellipsoid, Meters and transformed to the project Coordinate Reference System (CRS) upon ingest into GeoCue before project wide lidar matching.

The Leica HxMap pre-processing software created raw swath files with all return values. This multi-return information was processed and classified to obtain the required feature for delivery. All lidar data is processed using the ASPRS binary LAS format version 1.4. **Table 4** illustrates the achieved point cloud statistics.

Category	Value
Aggregate Total Points	94,812,059,855
Aggregate Nominal Pulse Spacing (m)	0.46
Aggregate Nominal Pulse Density (pls/m²)	4.7
Aggregate Nominal Pulse Spacing (ft)	1.51
Aggregate Nominal Pulse Density (pls/ft²)	0.4

Table 4: Point Cloud Statistics

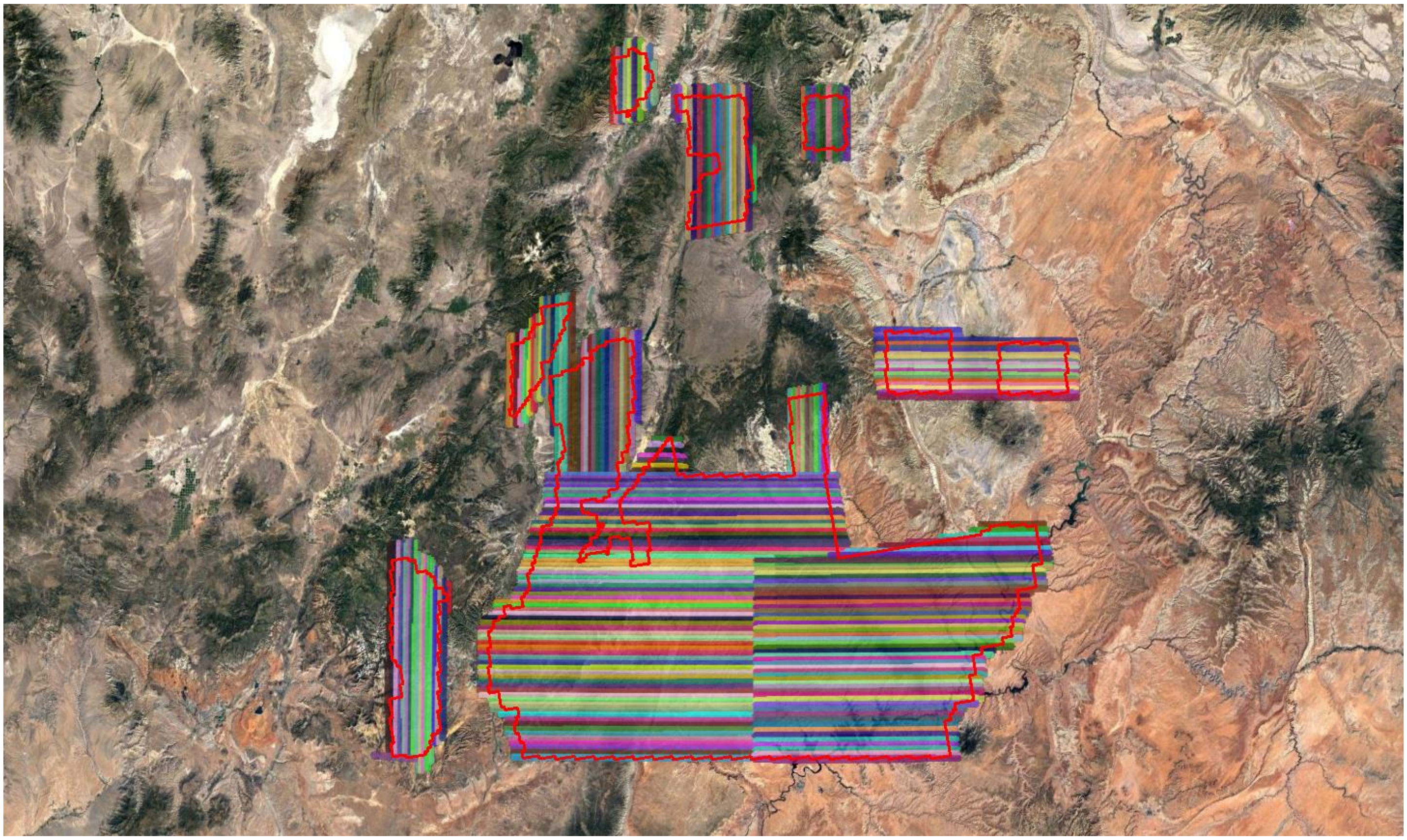


Figure 3: Raw Point Cloud Coverage

3.2 Coordinate Reference System

Horizontal Datum:	North American Datum of 1983 (2011)
Projection:	Universal Transverse Mercator Zone 12 North
Vertical Datum:	North American Vertical Datum of 1988
Geoid Model:	Geoid12B
Units:	Meters

3.3 Lidar Matching

Sanborn uses Leica HxMap software and the latest boresight values to combine the processed SBET with the laser scan files to produce the lidar point cloud. The data is processed by mission and/or block and is output in ASPRS LASv1.4 Point Data Record Format (PDRF) 6 with 16bit linearly scaled intensities to the nearest 0.001 3D position. Each mission is produced in WGS84, UTM, Ellipsoid, Meters and transformed to the project CRS upon import into GeoCue.

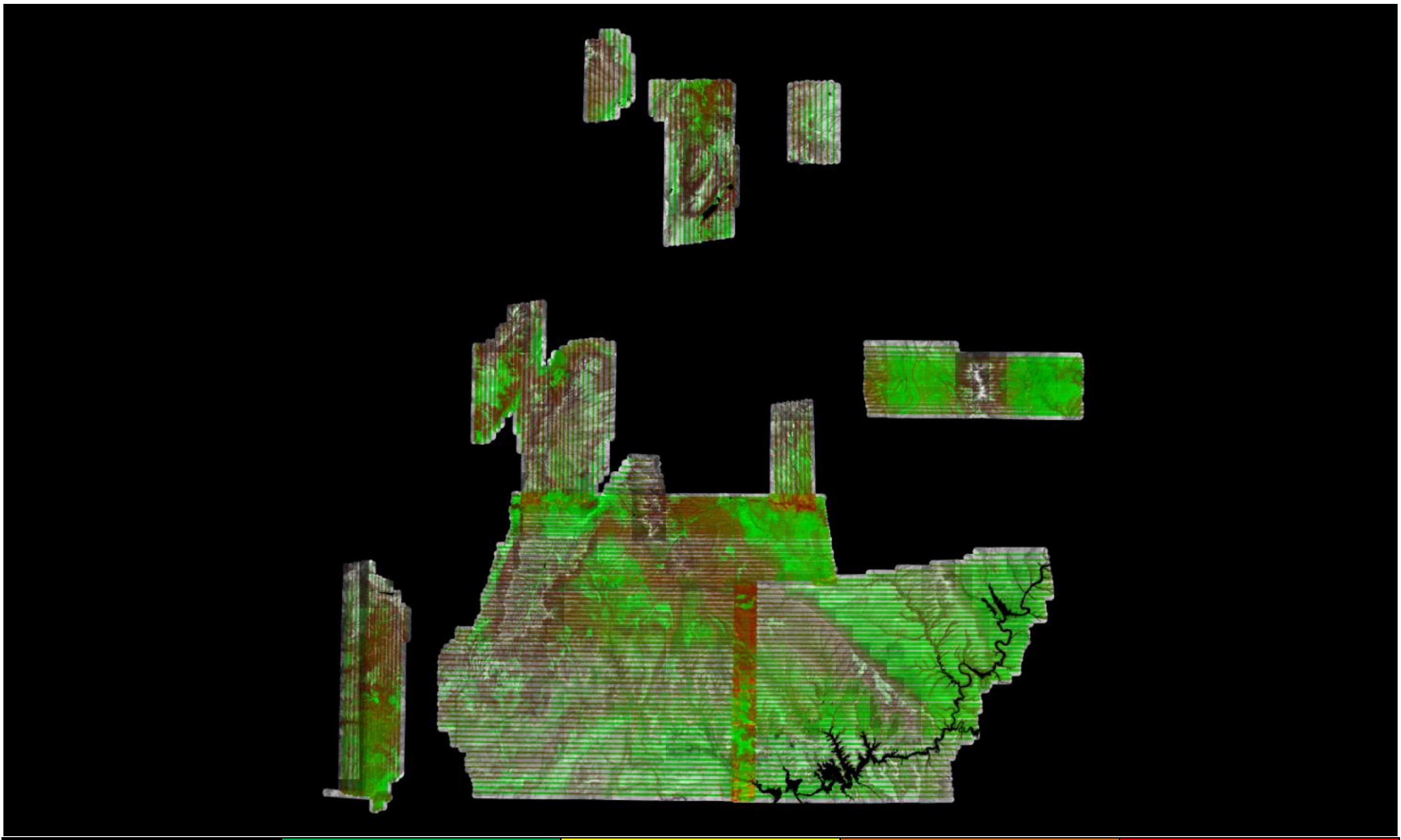
Each mission in imported into GeoCue where each individual flight line is assigned a unique flight line number. The SBET is cut per mission into TerraScan Trajectory files based on flight line number and timestamp to be utilized during the lidar natching process. The project area(s) are broken into logical blocks based on AOIs or predetermined delivery blocks and the individual flight lines are populated into lidar matching tile grids. These lidar matching tile grids are prepared for scanner, line, mission, block and eventual project wide lidar matching routines by first running point cloud filters to identify ground and building features to be used during any TerraMatch processes.

After successful point cloud filters have been run on the lidar matching dataset TerraMatch is used to extract Tie Line Observations. TerraMatch Tie Lines are 3D vectors extracted from the lidar point cloud intended to reduce the overwhelming data size to a more manageable amount. Each Tie Line is extracted using a series of parameters designed to identify features such a flat or sloping ground or roofline apexes that geospatially correlates to the same observation of an overlapping flight line. These observed 3D vectors are then utilized across multiple solution iterations to reduce the average offset from line to line, mission to mission, and block to block. TerraMatch Solutions are calculated to adjust Roll, Heading, Pitch, Mirror Scale, X, Y and Z in combination to reduce the Root Mean Square Deviation (RMSDr and RMSDz). These solutions are calculated, applied, and reviewed throughout the lidar matching process.

Sanborn takes advantage of both visual and statistical validation methodologies to review and ensure overlap consistency of the lidar data meets and/or exceeds project specifications. Differential Elevation (dZ) rasters are color ramp (Dark Green, Green, Yellow, Orange, Red) based visual representations produced to identify vertical offsets between flight lines. The dZ rasters are reviewed in their entirety for flight lines and areas that exceed the required RMSDz. Furthermore, an additional set of TerraMatch Tie Lines are produced after solutions are applied and a Tie Line Report is produced to assess the X. Y. and Z offset averages and magnitudes for the whole project including each line individually. This visual and statistical review guarantees the relative accuracy of the lidar dataset. **Table 5** outlines the relative accuracy requirements of the project. **Tables 6 – 9** are the relative accuracies achieved.

Category	Value (m)	Value (ft)
Smooth Surface Repeatability	≤0.060	≤0.197
Swath overlap difference, RMSDz	≤0.080	≤0.262

Table 5: Relative Accuracy Requirements



No Data	< 0.08m	0.08m to 0.16m	0.16m to 0.24m	> 0.24m
No Data	< 0.262ft	0.262ft to 0.524ft	0.524ft to 0.786ft	> 0.786ft

Figure 4: Swath Separation Images

Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
1	-	-	0.008	**583**	0.006	0.003	0.008	**676**	0.023	0.018	0.009
2	-	-	0.007	**584**	0.012	0.006	0.008	**677**	0.022	0.020	0.008
3	0.009	0.035	0.008	**585**	0.014	0.007	0.008	**678**	0.013	0.012	0.007
4	0.009	0.035	0.007	**586**	0.029	0.015	0.009	**679**	0.020	0.004	0.009
5	0.019	0.011	0.008	**587**	0.029	0.014	0.008	**680**	0.010	0.002	0.008
6	0.017	0.014	0.008	**588**	0.062	0.087	0.009	**681**	-	-	0.009
7	0.026	0.032	0.008	**589**	0.044	0.066	0.009	**682**	-	-	0.008
8	0.017	0.021	0.008	**590**	0.007	0.013	0.009	**683**	-	-	0.009
9	0.019	0.018	0.008	**591**	0.014	0.015	0.009	**684**	-	-	0.009
10	0.022	0.014	0.008	**592**	0.014	0.015	0.009	**685**	-	-	0.009
11	0.016	0.012	0.008	**593**	-	-	0.010	**687**	0.041	0.063	0.009
12	0.017	0.029	0.008	**594**	-	-	0.008	**688**	0.030	0.018	0.008
14	0.015	0.043	0.007	**595**	-	-	0.010	**689**	0.033	0.019	0.008
15	0.015	0.021	0.008	**596**	-	-	0.008	**690**	0.014	0.026	0.008
16	0.014	0.020	0.008	**597**	-	-	0.008	**691**	0.012	0.028	0.007
17	0.022	0.018	0.008	**598**	-	-	0.008	**692**	0.020	0.032	0.007
18	0.034	0.026	0.007	**599**	-	-	0.009	**693**	0.021	0.025	0.007
19	-	-	0.009	**600**	0.011	0.004	0.008	**694**	0.016	0.019	0.008
20	0.008	0.016	0.009	**601**	0.008	0.004	0.009	**695**	0.014	0.019	0.009
21	0.008	0.016	0.009	**602**	-	-	0.008	**696**	0.012	0.025	0.009

22	-	-	0.007	**603**	-	-	0.009	**697**	0.018	0.026	0.008
23	-	-	0.009	**604**	-	-	0.007	**698**	0.032	0.031	0.008
24	0.018	0.018	0.008	**605**	-	-	0.008	**699**	0.029	0.030	0.008
25	0.015	0.013	0.008	**606**	-	-	0.007	**700**	0.018	0.020	0.009
26	-	-	0.008	**607**	-	-	0.008	**701**	0.018	0.018	0.010
27	-	-	0.007	**608**	-	-	0.010	**702**	0.018	0.026	0.011
28	-	-	0.008	**609**	-	-	0.010	**703**	0.046	0.034	0.011
29	0.034	0.048	0.008	**610**	-	-	0.011	**705**	0.021	0.014	0.008
30	0.033	0.048	0.007	**611**	0.042	0.024	0.011	**706**	0.024	0.016	0.008
32	-	-	0.008	**612**	0.030	0.022	0.011	**707**	-	-	0.008
33	-	-	0.008	**613**	0.017	0.021	0.012	**708**	0.050	0.072	0.008
34	0.019	0.019	0.009	**614**	0.018	0.024	0.014	**709**	0.063	0.078	0.008
35	0.021	0.017	0.008	**615**	0.025	0.023	0.013	**710**	-	-	0.009
36	0.025	0.016	0.008	**616**	0.044	0.041	0.011	**711**	0.030	0.023	0.009
37	0.019	0.020	0.008	**619**	0.012	0.012	0.008	**712**	0.028	0.023	0.007
38	0.015	0.017	0.009	**620**	0.012	0.012	0.006	**713**	0.039	0.029	0.007
39	0.013	0.012	0.008	**621**	0.007	0.020	0.008	**714**	-	-	0.007
40	0.016	0.015	0.008	**622**	-	-	0.007	**715**	0.008	0.023	0.008
41	0.018	0.012	0.008	**623**	0.021	0.007	0.008	**716**	0.008	0.040	0.008
499	0.014	0.025	0.010	**624**	0.025	0.008	0.008	**717**	0.001	0.038	0.008
500	0.015	0.024	0.010	**625**	0.023	0.024	0.009	**718**	0.009	0.018	0.009
501	0.024	0.018	0.009	**626**	0.019	0.032	0.013	**720**	0.019	0.030	0.010
502	0.023	0.017	0.009	**627**	0.017	0.030	0.012	**721**	0.031	0.020	0.009
503	0.025	0.025	0.009	**628**	0.013	0.020	0.013	**722**	0.011	0.019	0.011
504	0.022	0.021	0.010	**629**	0.012	0.016	0.011	**723**	0.015	0.024	0.009
505	0.021	0.019	0.011	**630**	0.018	0.017	0.011	**724**	-	-	0.010
506	0.017	0.013	0.009	**631**	0.017	0.013	0.010	**725**	-	-	0.008
507	0.013	0.015	0.006	**632**	0.015	0.016	0.007	**726**	0.034	0.036	0.008
508	0.015	0.014	0.009	**633**	0.015	0.017	0.010	**727**	0.068	0.030	0.009
509	-	-	0.008	**634**	0.015	0.016	0.009	**728**	-	-	0.008
510	0.015	0.016	0.008	**635**	0.023	0.016	0.009	**729**	-	-	0.008
511	0.010	0.009	0.008	**636**	0.013	0.015	0.008	**730**	-	-	0.007
512	0.015	0.017	0.008	**637**	0.016	0.013	0.008	**731**	-	-	0.008
513	0.013	0.019	0.008	**638**	0.016	0.025	0.009	**732**	0.005	0.011	0.010
514	0.012	0.014	0.008	**639**	0.013	0.015	0.007	**733**	0.030	0.026	0.008
515	0.012	0.014	0.009	**640**	0.020	0.020	0.009	**734**	0.043	0.014	0.009
516	0.013	0.015	0.008	**641**	0.022	0.019	0.009	**735**	0.040	0.013	0.010
517	-	-	0.005	**642**	0.014	0.011	0.009	**736**	-	-	0.011
518	-	-	0.006	**650**	0.018	0.016	0.008	**737**	-	-	0.011
519	-	-	0.006	**651**	0.015	0.030	0.008	**738**	-	-	0.009
520	-	-	0.007	**652**	0.017	0.009	0.007	**739**	-	-	0.010
521	-	-	0.007	**653**	0.026	0.013	0.007	**740**	-	-	0.009
522	-	-	0.007	**654**	0.020	0.019	0.009	**741**	0.003	0.063	0.010
523	0.013	0.032	0.008	**656**	0.013	0.018	0.008	**742**	0.013	0.036	0.009
524	-	-	0.007	**658**	0.018	0.014	0.010	**743**	0.028	0.039	0.009
525	0.008	0.027	0.007	**659**	0.012	0.019	0.009	**744**	0.015	0.045	0.011
526	0.016	0.032	0.008	**660**	0.012	0.021	0.009	**745**	0.015	0.021	0.012
527	0.001	0.021	0.008	**661**	0.018	0.023	0.009	**746**	0.018	0.025	0.009

528	0.008	0.023	0.007	**662**	0.027	0.037	0.009	**747**	0.011	0.001	0.007
529	0.012	0.017	0.008	**663**	0.064	0.048	0.008	**748**	0.005	0.001	0.009
530	0.011	0.002	0.008	**664**	0.047	0.071	0.009	**749**	0.009	0.011	0.007
531	-	-	0.008	**665**	-	-	0.010	**750**	0.012	0.013	0.008
532	-	-	0.008	**666**	-	-	0.008	**751**	0.050	0.033	0.008
533	-	-	0.009	**667**	0.031	0.006	0.009	**752**	-	-	0.010
534	-	-	0.008	**668**	0.016	0.013	0.011	**753**	0.034	0.021	0.008
535	-	-	0.008	**669**	0.015	0.014	0.010	**754**	0.039	0.043	0.009
577	0.009	0.002	0.007	**670**	0.031	0.010	0.009	**755**	-	-	0.009
578	0.007	0.002	0.008	**671**	0.026	0.022	0.009	**756**	-	-	0.011
579	-	-	0.009	**672**	0.016	0.025	0.009	**757**	0.049	0.019	0.012
580	-	-	0.008	**673**	0.016	0.018	0.008	**758**	0.041	0.027	0.012
581	-	-	0.008	**674**	0.033	0.050	0.008	**759**	0.037	0.026	0.009
582	-	-	0.007	**675**	0.021	0.036	0.008				

Table 6: Average Magnitudes by Line (Meters)

Category	X	Y	Z
Average Magnitude	0.019	0.019	0.009
RMS Values	0.031	0.030	0.012
Maximum Values	0.151	0.157	0.160
Observation Weight	6899.0	6899.0	1679815.0

Table 7: Internal Observation Statistics (Meters)

Category	Mismatch
Average 3D Mismatch	0.00873
Average XY Mismatch	0.03316
Average Z Mismatch	0.00862

Table 8: Overall Relative Accuracy (Meters)

Category	Observations
Section Lines	739,406
Roof Lines	3,269

Table 9: Vector Observations

3.4 Lidar Classification

Lidar filtering was accomplished using GeoCue with TerraSolid processing and modeling software. The filtering process reclassifies all the data into classes within the point cloud classification scheme. Once the data is classified, the entire dataset is reviewed and manually edited for anomalies that are outside the required guidelines of the product specification or contract requirements. This can include, but is not limited to, classifying bridges, structures, filling culverts, and manually analyzing the bare-earth surface by classifying features that belong in non-extraneous classification codes. **Table 10** outlines the point classes leveraged in the lidar dataset.

Code	Description	Definition
1	Unclassified	Processed, but unclassified
2	Ground	Bare-earth surface
7	Low Noise	Erroneous returns below bare-earth surface
9	Water	Hydrologically identified water surface points
17	Bridge Decks	Structure carrying a means of transit of higher
18	High Noise	Erroneous atmospheric returns above bare-earth
20	Ignored Ground	Bare-earth points near breaklines
21	Snow	Unavoidable snow or snow pack
22	Temporal Exclusion	Nonfavored data in intertidal zones
Flag	Overlap	Overage points lying within overlapping areas of two or more swaths
Flag	Withheld	Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the

Table 10: Lidar Classification Scheme

3.5 Accuracy Assessment

The lidar dataset was evaluated using a total of two hundred and thirty-five (241) check points (140 NVA + 101 VVA). The end result provided a vertical accuracy that fell within project specifications. Please see the **Attachment A** for the full Vertical Accuracy Report and the project *Metadata* for an in-depth accuracy assessment. **Table 11** outlines the absolute accuracy requirements of the project. **Table 12** shows high level statistics and mean errors for the area processed by Sanborn.

Category	Value (m)	Value (ft)
RMSEz	≤0.100	≤0.328
@ 95-Percent Confidence Level	≤0.196	≤0.643
@ 95th Percentile	≤0.300	≤0.984

Table 11: Absolute Accuracy Requirements

Broad Land Cover Type	# of Points	RMSEz	95% Confidence Level	95th Percentile
NVA of Point Cloud	140	0.052	0.101	
NVA of Bare Earth	140	0.052	0.102	
NVA of DEM	140	0.052	0.101	
VVA of Bare Earth	101	0.067		0.135
VVA of DEM	101	0.061		0.130

Table 12: Vertical Accuracy Assessment of Check Points (Meters)

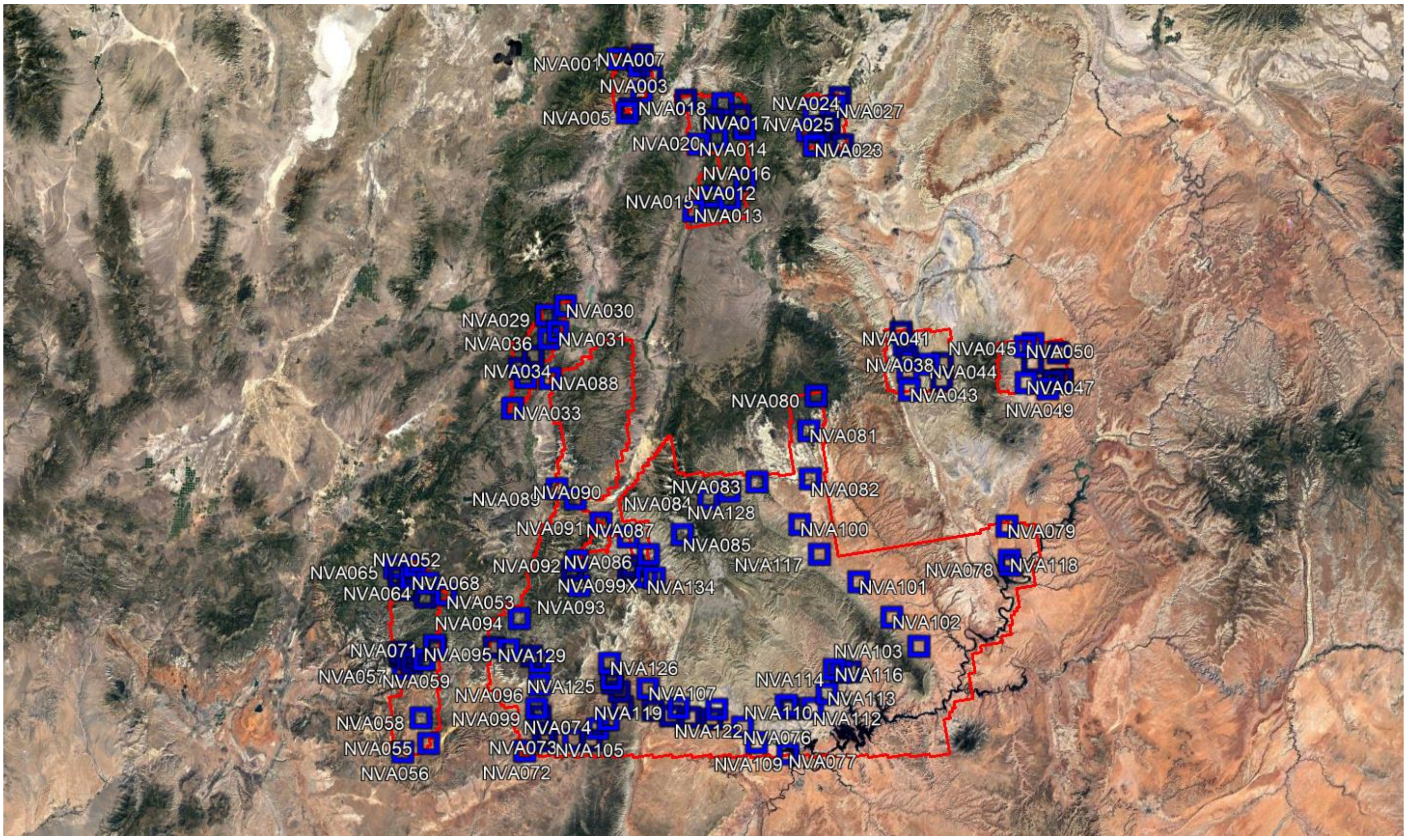


Figure 5: Non-vegetated Check Point Distribution

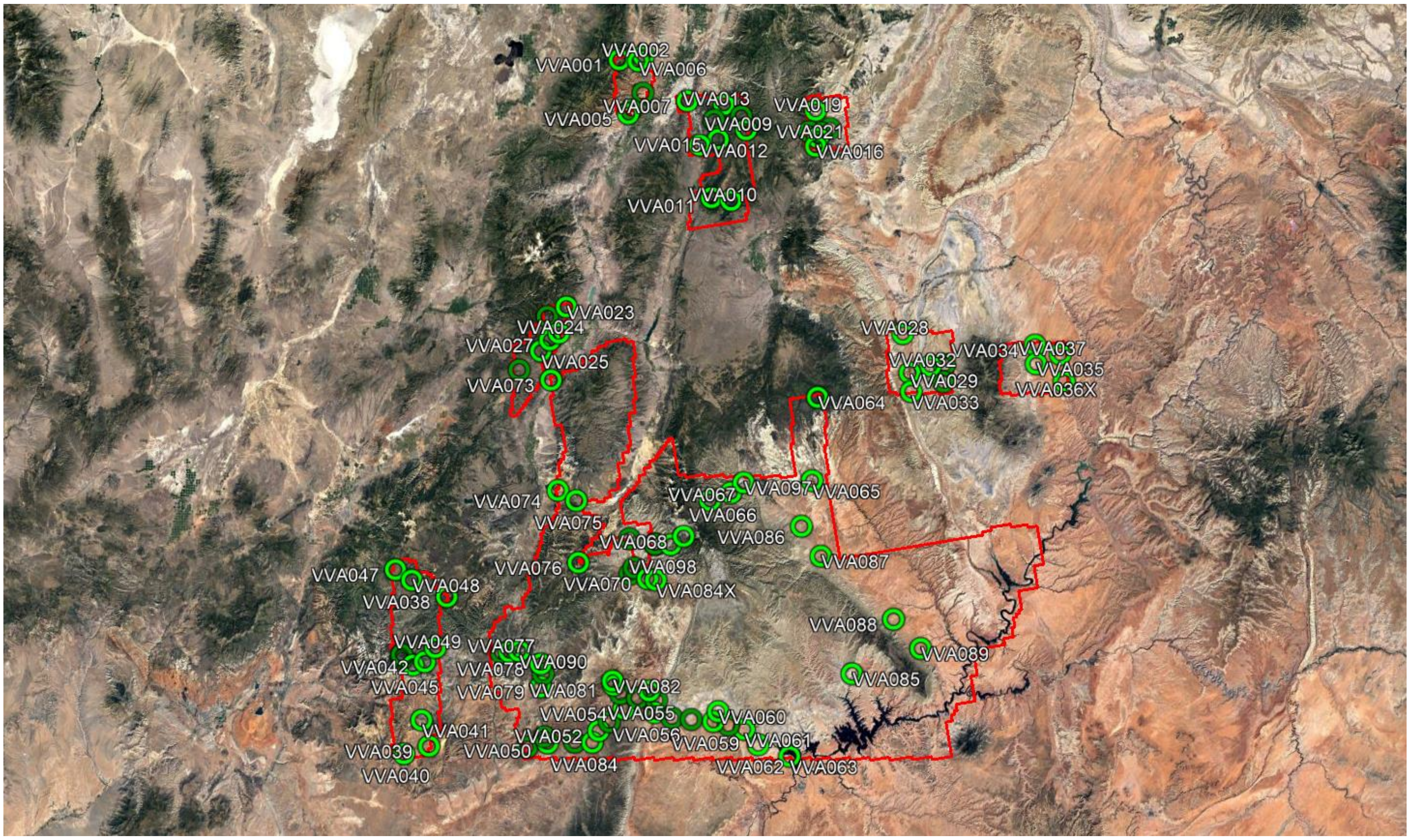


Figure 6: Vegetated Check Point Distribution

4.0 PRODUCT GENERATION

The following products were generated using the final coordinate system as defined in the contract:

Classified Point Cloud
The Classified Point Cloud, containing all returns, is delivered in LASv1.4 (*.las) format and meets project specifications. The Classified Point Cloud contains file names referencing the tile index.

Bare-Earth Digital Elevation Model
32-bit GeoTIFF (*.tif) elevation rasters were created from the bare-earth points in the processed lidar dataset and hydro-flattened breaklines. Each pixel contains an elevation.

First-Return Digital Surface Model
32-bit GeoTIFF (*.tif) elevation rasters were created from the first-return points in the processed lidar dataset. All overlap classes were ignored during this process. Each pixel contains an elevation.

First-Return Intensity Images
8-bit GeoTIFF (*.tiff) intensity rasters were created from the first-return points in the processed lidar dataset. All overlap classes were ignored during this process.

Swath Separation Images
24-bit GeoTIFF (*.tif) height separation rasters modulated by intensity were created from the last-return points in the processed lidar dataset.

Swath Polygons
Polygons features representing either the convex or concave hull of swaths, where each record is an individual swath or channel within a swath. Delivered in Esri (*.shp) format.

Other Deliverables
Breaklines
Metadata
Vertical Accuracy Report

A final quality assurance process was undertaken to validate all deliverables for the project. Prior to release of data for delivery, Sanborn's Quality Control/Quality Assurance department reviews the data and then releases it for delivery.