AGRC Southern Utah Lidar (QL2 Block3)
312020335

Lidar Report

January, 2021

EXECUTIVE SUMMARY

The Utah Automated Geographic Reference Center (AGRC) contracted with The Sanborn Map Company, Inc. (Sanborn) to provide remote sensing services 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 ~4,976mi² was completed on July 29th, 2020.

The Leica TerrainMapper was 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

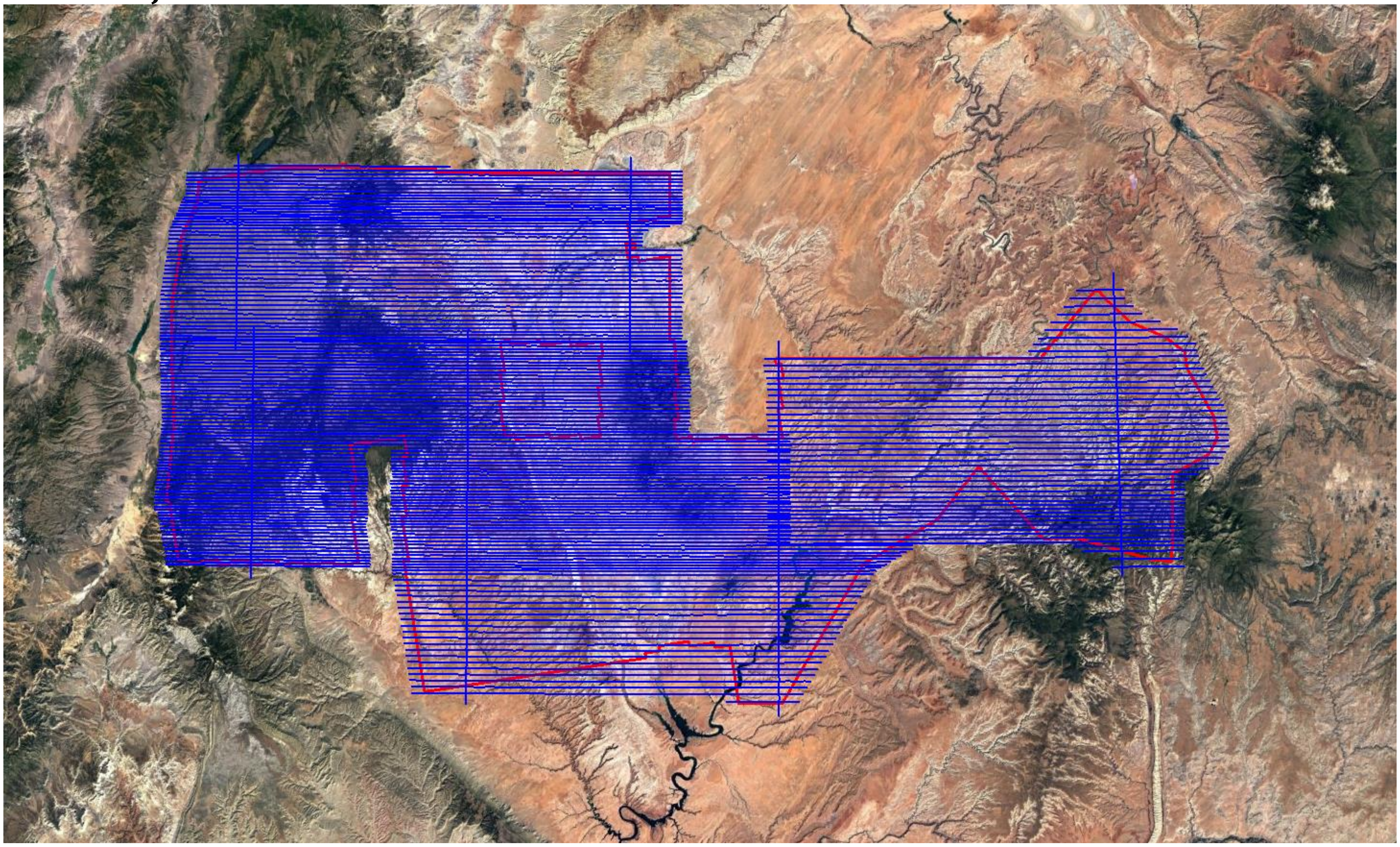


Figure 1: DPA and Trajectories As-Flown

2.0 ACQUISITION

2.1 Introduction

This section outlines the lidar system, flight reporting and data acquisition methodology used during the collection of the QL2 Block3 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.

Acquisition Parameters	
Sensor	Leica TerrainMapper
Flying Height (AGL) (m)	3050
Air Speed (kts)	150
Field of View (degrees)	40
Overlap (%)	20
Pulse Rate (kHz)	613.6
Scan Rate (Hz)	82.2
Laser Footprint (m)	0.71
Multi-Pulse	Yes
Point Spacing (m)	0.66
Point Density (pls/m²)	2.3
Swath Width (m)	2220

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 forty (40) 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)
6/10/2020	Leica TerrainMapper	TM91555	N2326B	20200610A	1.5	16:41:31	21:02:46
6/11/2020	Leica TerrainMapper	TM91556	N2326B	20200611A	1.5	15:50:01	19:39:10
6/11/2020	Leica TerrainMapper	TM91557	N2326B	20200611B	1.6	21:17:01	22:16:26
6/12/2020	Leica TerrainMapper	TM91558	N2326B	20200612A	1.7	14:43:37	18:42:30
6/12/2020	Leica TerrainMapper	TM91559	N2326B	20200612B	1.5	19:59:22	22:31:38
6/13/2020	Leica TerrainMapper	TM91560	N2326B	20200613A	1.5	13:18:55	16:35:00
6/13/2020	Leica TerrainMapper	TM91561	N2326B	20200613B	1.6	17:39:55	19:15:23
6/14/2020	Leica TerrainMapper	TM91562	N2326B	20200614A	1.4	12:02:13	15:55:50
6/14/2020	Leica TerrainMapper	TM91563	N2326B	20200614B	1.4	17:19:10	18:50:59
6/15/2020	Leica TerrainMapper	TM91564	N2326B	20200615A	1.5	12:16:10	16:04:50

6/16/2020	Leica TerrainMapper	TM91565	N2326B	20200616A	1.5	11:49:46	15:36:33
6/17/2020	Leica TerrainMapper	TM91566	N2326B	20200617A	1.5	11:50:01	14:23:41
6/18/2020	Leica TerrainMapper	TM91567	N2326B	20200618A	1.4	19:02:15	21:48:44
6/20/2020	Leica TerrainMapper	TM91568	N2326B	20200620A	1.4	12:23:37	15:54:41
6/20/2020	Leica TerrainMapper	TM91569	N2326B	20200620B	1.4	11:56:03	17:08:45
6/21/2020	Leica TerrainMapper	TM91570	N2326B	20200621A	1.5	17:29:07	19:57:19
6/21/2020	Leica TerrainMapper	TM91571	N2326B	20200621B	1.5	17:42:22	20:42:28
6/22/2020	Leica TerrainMapper	TM91572	N2326B	20200622A	1.5	11:56:03	17:08:45
6/23/2020	Leica TerrainMapper	TM91573	N2326B	20200623A	1.5	11:45:33	15:35:37
6/24/2020	Leica TerrainMapper	TM91574	N2326B	20200624A	1.4	11:50:22	16:59:38
6/24/2020	Leica TerrainMapper	TM91575	N2326B	20200624B	1.4	12:23:43	16:55:22
6/27/2020	Leica TerrainMapper	TM91520	N500Q	20200627A	1.4	17:10:58	18:47:57
6/30/2020	Leica TerrainMapper	TM91521	N500Q	20200630A	1.5	14:57:28	17:11:41
7/1/2020	Leica TerrainMapper	TM91522	N500Q	20200701A	1.5	13:14:13	17:21:19
7/2/2020	Leica TerrainMapper	TM91523	N500Q	20200702A	1.6	13:15:19	17:08:09
7/7/2020	Leica TerrainMapper	TM91524	N500Q	20200707A	1.7	12:41:37	17:20:23
7/8/2020	Leica TerrainMapper	TM91525	N500Q	20200708A	1.5	13:23:18	17:31:07
7/9/2020	Leica TerrainMapper	TM91526	N500Q	20200709A	1.5	13:21:43	17:08:19
7/11/2020	Leica TerrainMapper	TM91527	N500Q	20200711A	1.6	14:04:58	16:43:19
7/12/2020	Leica TerrainMapper	TM91528	N500Q	20200712A	1.4	13:14:46	16:43:06
7/18/2020	Leica TerrainMapper	TM91529	N500Q	20200718A	1.8	12:59:31	16:47:31
7/19/2020	Leica TerrainMapper	TM91530	N500Q	20200719A	1.6	14:38:01	17:12:18
7/20/2020	Leica TerrainMapper	TM91531	N500Q	20200720A	1.6	12:39:31	16:00:12
7/23/2020	Leica TerrainMapper	TM91532	N500Q	20200723A	1.4	12:19:18	15:58:41
7/24/2020	Leica TerrainMapper	TM91533	N500Q	20200724A	1.7	13:47:16	16:24:07
7/25/2020	Leica TerrainMapper	TM91534	N500Q	20200725A	1.7	15:36:58	17:04:50
7/26/2020	Leica TerrainMapper	TM91535	N500Q	20200726A	1.7	13:20:39	15:32:37
7/27/2020	Leica TerrainMapper	TM91536	N500Q	20200727A	1.6	13:10:28	16:26:35
7/28/2020	Leica TerrainMapper	TM91537	N500Q	20200728A	1.7	13:09:49	17:03:38
7/29/2020	Leica TerrainMapper	TM91538	N500Q	20200729A	1.4	13:12:34	16:52:42

Table 2: Collection Date Time by Mission

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
610	SetPoint	n/a	37 26 28.68727	110 33 43.66307	1314.256
614	SetPoint	n/a	37 32 34.87384	110 42 49.72748	1242.651
622	SetPoint	n/a	38 45 34.19208	109 44 40.08278	1373.202
627	SetPoint	n/a	37 44 46.22824	111 34 10.20522	1726.076
630	SetPoint	n/a	37 42 03.40618	112 09 22.68461	2294.739
701	SetPoint	n/a	37 42 14.16946	112 09 13.87127	2309.535
709	SetPoint	n/a	37 44 46.23781	111 34 10.21645	1726.997
718	SetPoint	n/a	38 24 49.18374	110 41 50.34880	1330.309
725	SetPoint	n/a	38 24 50.95508	110 41 49.61944	1341.244
926	SetPoint	n/a	39 06 22.75700	108 32 01.46796	1433.627
929	SetPoint	n/a	37 18 14.26111	108 37 41.33158	1779.124
MC04	CORS	DH6916	38 41 02.97506	108 58 25.82380	1401.694
MC09	CORS	DL3642	38 14 35.61438	108 33 29.28319	1793.798
P012	CORS	DI3419	38 05 50.74019	109 20 01.76296	1789.333

Table 3: GNSS Reference Station Coordinates

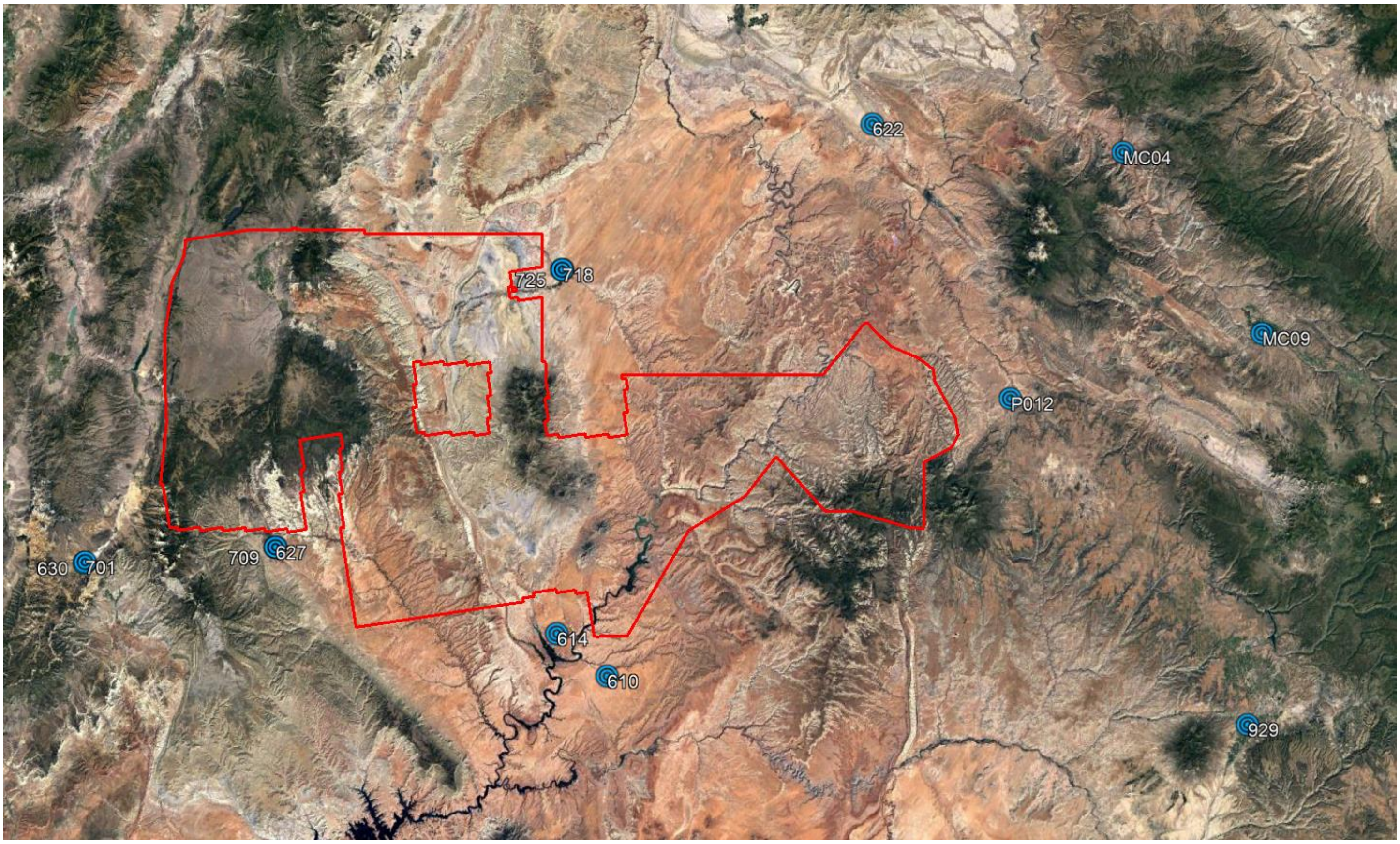


Figure 2: GNSS Reference Stations

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	111,965,201,046
Aggregate Nominal Pulse Spacing (m)	0.39
Aggregate Nominal Pulse Density (pls/m²)	6.6
Aggregate Nominal Pulse Spacing (ft)	1.27
Aggregate Nominal Pulse Density (pls/ft²)	0.6

Table 4: Point Cloud Statistics

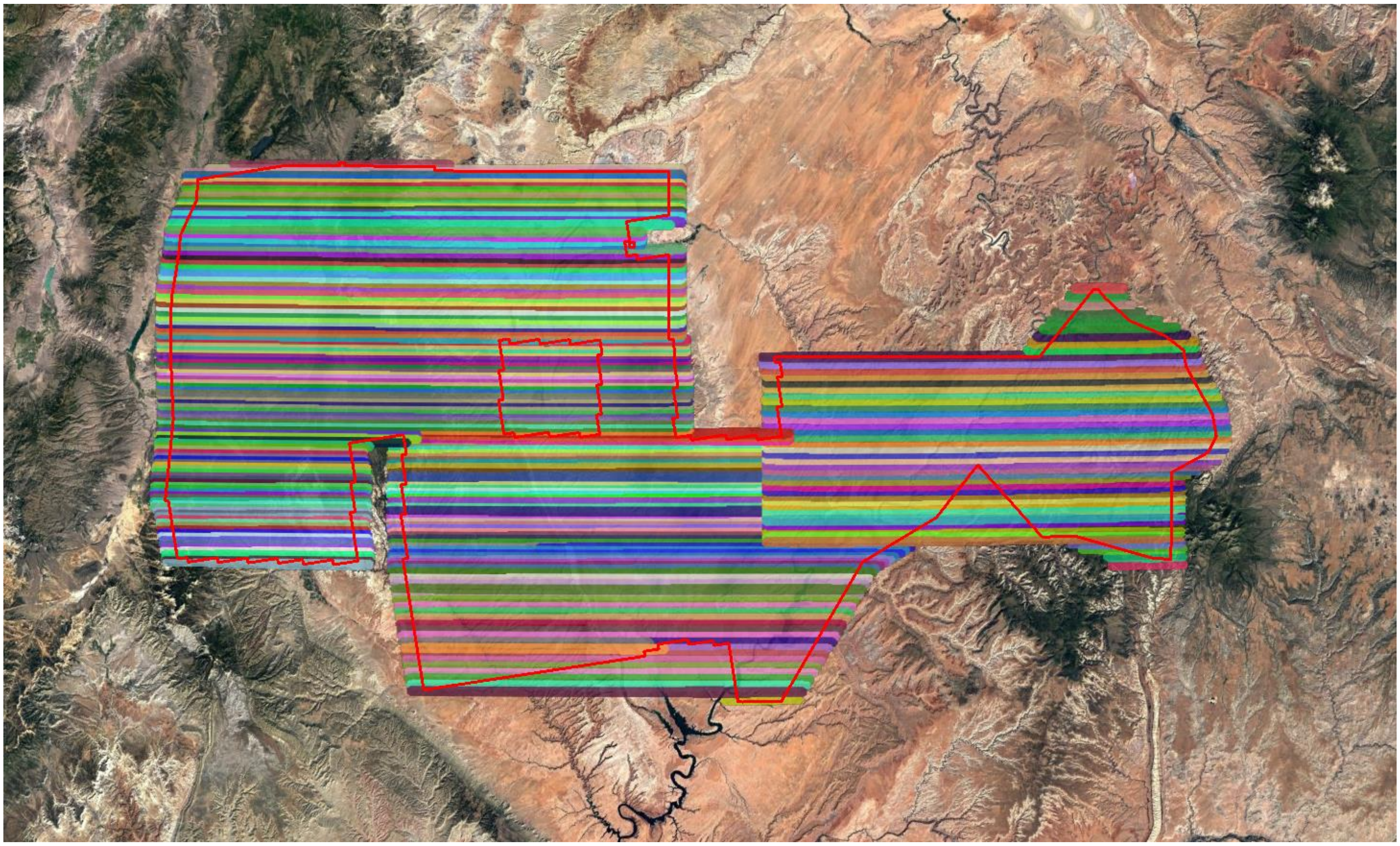


Figure 3: Raw Point Cloud Coverage

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.

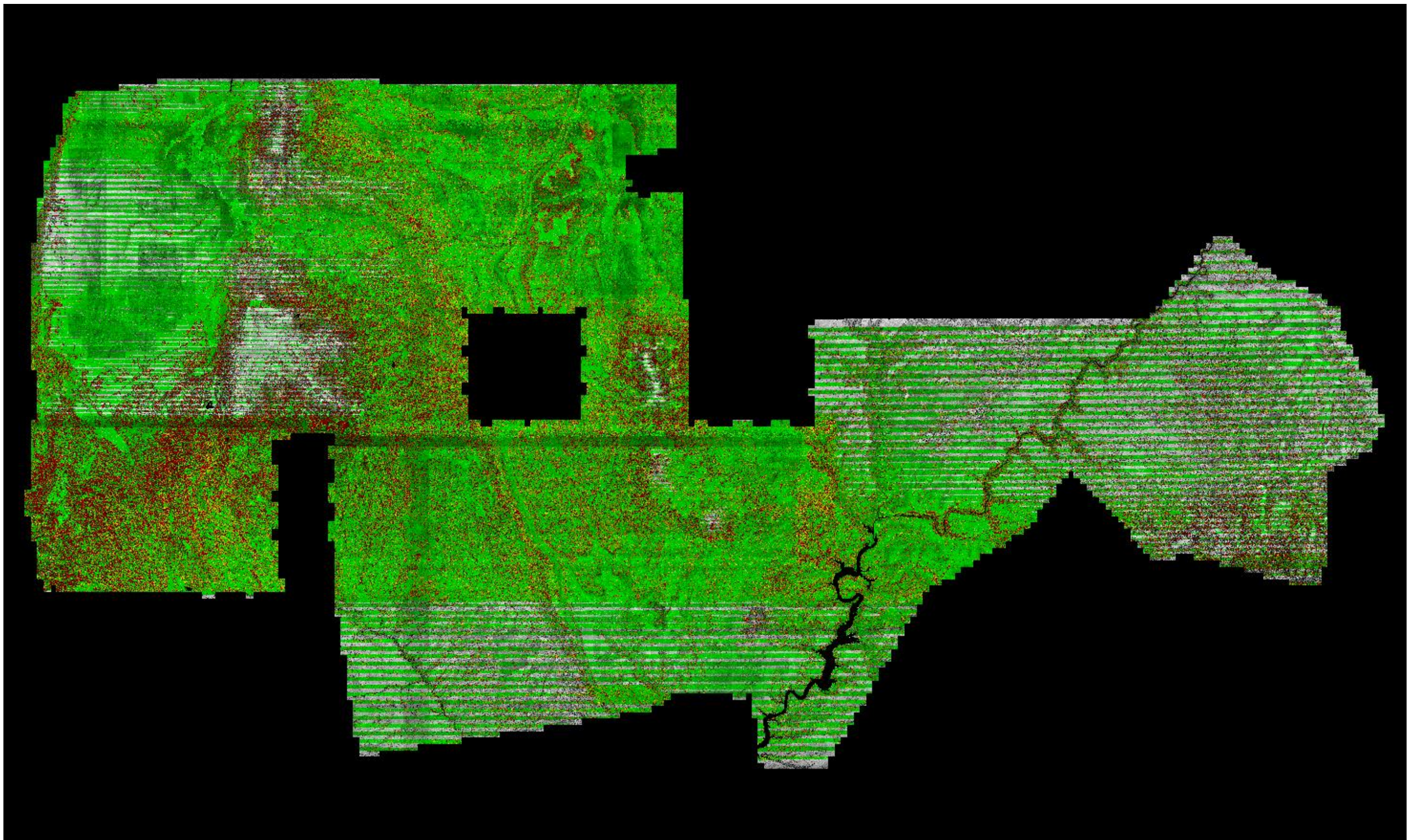
Each mission is imported into GeoCue where each individual flight line is assigned a unique Source ID number. The SBET is cut per swath into TerraScan Trajectory files based on Source ID number and timestamp; these are utilized during the lidar matching process. The project area(s) are broken into logical 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 number. 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 correlate to the same observation of an overlapping flight line.

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. Height Separation Rasters modulated by Intensity are representative of the interswath alignment and provide a holistic qualitative look at the positional quality of the point cloud. The dZ rasters are reviewed in their entirety for flight lines and areas that exceed the required RMSDz. Furthermore, the set of TerraMatch Tie Lines are used to produce a Tie Line Report to statistically 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
401	0.064	0.012	0.030	**482**	0.058	0.011	0.030	**562**	0.056	0.013	0.023
402	0.067	0.015	0.030	**483**	0.061	0.011	0.034	**563**	0.050	0.012	0.019
403	0.067	0.013	0.032	**484**	0.062	0.012	0.029	**564**	0.052	0.012	0.020
404	0.065	0.012	0.035	**485**	0.060	0.011	0.029	**565**	0.051	0.011	0.015
405	0.061	0.012	0.037	**486**	0.064	0.011	0.040	**566**	0.056	0.013	0.019
406	0.064	0.012	0.028	**487**	0.064	0.013	0.029	**567**	0.049	0.010	0.020
407	0.064	0.012	0.032	**488**	0.064	0.012	0.029	**568**	0.057	0.011	0.021
408	0.063	0.011	0.031	**489**	0.061	0.012	0.027	**569**	0.063	0.013	0.024
409	0.056	0.010	0.033	**490**	0.053	0.011	0.033	**570**	0.056	0.011	0.020
410	0.058	0.010	0.036	**491**	0.066	0.014	0.028	**571**	0.045	0.026	0.028
411	0.060	0.011	0.025	**492**	0.060	0.012	0.029	**572**	0.049	0.011	0.015
412	0.059	0.012	0.025	**493**	0.066	0.014	0.032	**573**	0.054	0.012	0.019
413	0.057	0.011	0.031	**494**	0.061	0.012	0.028	**574**	0.056	0.013	0.020
414	0.055	0.012	0.028	**495**	0.056	0.011	0.038	**575**	0.062	0.013	0.021
415	0.051	0.010	0.030	**496**	0.062	0.012	0.029	**576**	0.058	0.012	0.019
416	0.061	0.012	0.031	**497**	0.061	0.011	0.035	**577**	0.042	0.030	0.026
417	0.060	0.012	0.029	**498**	0.068	0.012	0.036	**578**	0.054	0.012	0.019
418	0.054	0.012	0.029	**499**	0.064	0.012	0.036	**579**	0.051	0.011	0.015
419	0.055	0.012	0.024	**500**	0.066	0.013	0.030	**580**	0.064	0.014	0.023
420	0.071	0.029	0.033	**501**	0.065	0.013	0.036	**581**	0.055	0.011	0.018

421	0.053	0.010	0.028	**502**	0.036	0.034	0.031	**582**	0.052	0.010	0.019
422	0.053	0.010	0.031	**503**	0.058	0.013	0.032	**583**	0.050	0.009	0.014
423	0.053	0.010	0.026	**504**	0.059	0.011	0.039	**584**	0.054	0.011	0.019
424	0.054	0.010	0.027	**505**	0.059	0.012	0.033	**585**	0.052	0.011	0.018
425	0.049	0.009	0.026	**506**	0.056	0.011	0.032	**586**	0.066	0.014	0.021
426	0.060	0.013	0.026	**507**	0.066	0.013	0.032	**587**	0.069	0.013	0.028
427	0.051	0.011	0.030	**508**	0.059	0.011	0.032	**588**	0.051	0.010	0.018
428	0.055	0.011	0.031	**509**	0.056	0.011	0.029	**589**	0.055	0.010	0.019
429	0.055	0.011	0.032	**510**	0.061	0.013	0.029	**590**	0.050	0.010	0.017
430	0.055	0.011	0.029	**511**	0.079	0.023	0.028	**591**	0.054	0.011	0.019
431	0.066	0.013	0.031	**512**	0.062	0.019	0.031	**592**	0.060	0.011	0.028
432	0.067	0.013	0.030	**513**	0.059	0.022	0.028	**593**	0.060	0.012	0.031
433	0.064	0.011	0.031	**514**	0.062	0.013	0.028	**594**	0.054	0.011	0.022
434	0.061	0.011	0.032	**515**	0.057	0.018	0.028	**595**	0.053	0.011	0.018
435	0.060	0.011	0.032	**516**	0.041	0.026	0.027	**596**	0.056	0.011	0.021
436	0.063	0.013	0.028	**517**	0.061	0.012	0.021	**597**	0.054	0.010	0.020
437	0.057	0.012	0.027	**518**	0.046	0.009	0.016	**598**	0.054	0.010	0.021
438	0.067	0.014	0.031	**519**	0.054	0.010	0.021	**599**	0.057	0.010	0.023
439	0.055	0.011	0.041	**520**	0.057	0.012	0.018	**600**	0.056	0.011	0.025
440	0.055	0.010	0.027	**521**	0.063	0.014	0.022	**601**	0.059	0.012	0.031
441	0.058	0.010	0.028	**522**	0.067	0.016	0.025	**602**	0.063	0.013	0.028
442	0.058	0.010	0.026	**523**	0.065	0.015	0.024	**603**	0.059	0.013	0.028
443	0.057	0.010	0.029	**524**	0.059	0.015	0.025	**604**	0.051	0.012	0.024
444	0.058	0.010	0.027	**525**	0.056	0.014	0.024	**605**	0.056	0.013	0.027
445	0.056	0.010	0.031	**526**	0.052	0.012	0.023	**606**	0.056	0.014	0.028
446	0.054	0.009	0.028	**527**	0.050	0.011	0.022	**607**	0.058	0.013	0.032
447	0.055	0.010	0.031	**528**	0.048	0.010	0.021	**608**	0.061	0.014	0.033
448	0.068	0.012	0.029	**529**	0.055	0.010	0.023	**609**	0.058	0.012	0.033
449	0.071	0.011	0.041	**530**	0.057	0.011	0.023	**610**	0.048	0.010	0.020
450	0.064	0.011	0.025	**531**	0.060	0.013	0.026	**611**	0.061	0.013	0.023
451	0.056	0.010	0.027	**532**	0.053	0.012	0.023	**612**	0.058	0.013	0.021
452	0.051	0.009	0.026	**533**	0.053	0.011	0.022	**613**	0.064	0.014	0.024
453	0.050	0.008	0.027	**534**	0.059	0.013	0.021	**614**	0.049	0.010	0.021
454	0.053	0.009	0.028	**535**	0.058	0.013	0.025	**615**	0.060	0.013	0.023
455	0.050	0.008	0.028	**536**	0.057	0.012	0.024	**616**	0.047	0.011	0.018
456	0.061	0.010	0.031	**537**	0.057	0.012	0.023	**617**	0.052	0.012	0.017
457	0.054	0.009	0.028	**538**	0.051	0.010	0.022	**618**	0.047	0.011	0.023
458	0.058	0.010	0.032	**539**	0.051	0.011	0.020	**619**	0.036	0.024	0.021
459	0.057	0.010	0.030	**540**	0.049	0.010	0.017	**620**	0.044	0.009	0.014
460	0.058	0.011	0.028	**541**	0.054	0.011	0.019	**621**	0.065	0.017	0.027
461	0.049	0.009	0.032	**542**	0.050	0.010	0.018	**622**	0.055	0.010	0.019
462	0.054	0.009	0.030	**543**	0.062	0.013	0.025	**623**	0.053	0.010	0.018
463	0.060	0.013	0.029	**544**	0.055	0.012	0.023	**624**	0.057	0.011	0.021
464	0.044	0.031	0.033	**545**	0.062	0.013	0.025	**625**	0.039	0.009	0.018
465	0.050	0.010	0.028	**546**	0.057	0.012	0.027	**626**	0.034	0.036	0.026
466	0.055	0.011	0.025	**547**	0.052	0.011	0.025	**627**	0.059	0.012	0.022
467	0.061	0.025	0.029	**548**	0.049	0.012	0.021	**628**	0.053	0.011	0.019
468	0.048	0.020	0.029	**549**	0.054	0.011	0.021	**629**	0.059	0.012	0.025

469	0.061	0.017	0.028	**550**	0.054	0.012	0.020	**630**	0.052	0.011	0.018
470	0.056	0.017	0.026	**551**	0.060	0.011	0.022	**631**	0.058	0.011	0.022
471	0.064	0.017	0.029	**552**	0.054	0.011	0.020	**632**	0.051	0.010	0.018
472	0.064	0.016	0.034	**553**	0.056	0.011	0.020	**633**	0.060	0.012	0.023
473	0.061	0.013	0.032	**554**	0.054	0.011	0.020	**634**	0.053	0.010	0.018
474	0.052	0.012	0.027	**555**	0.054	0.012	0.021	**635**	0.054	0.010	0.019
475	0.063	0.013	0.032	**556**	0.051	0.011	0.020	**636**	0.056	0.011	0.024
476	0.053	0.011	0.035	**557**	0.051	0.011	0.020	**637**	0.053	0.012	0.025
477	0.056	0.011	0.027	**558**	0.044	0.009	0.017	**638**	0.045	0.011	0.019
478	0.059	0.013	0.030	**559**	0.050	0.010	0.020	**639**	0.048	0.011	0.019
479	0.059	0.011	0.030	**560**	0.048	0.009	0.019	**640**	0.040	0.010	0.019
480	0.060	0.012	0.034	**561**	0.053	0.010	0.018	**641**	0.055	0.012	0.023
481	0.051	0.011	0.026								

Table 6: Average Magnitudes by Line (Meters)

Category	X	Y	Z
Average Magnitude	0.056	0.011	0.026
RMS Values	0.068	0.019	0.034
Maximum Values	0.204	0.153	0.160
Observation Weight	217845.0	217845.0	1175741.0

Table 7: Internal Observation Statistics (Meters)

Category	Mismatch
Average 3D Mismatch	0.03397
Average XY Mismatch	0.05838
Average Z Mismatch	0.02586

Table 8: Overall Relative Accuracy (Meters)

Category	Observations
Section Lines	476,018
Roof Lines	1,747

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 one hundred and eight (108) check points (63 NVA + 45 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	63	0.085	0.167	
NVA of Bare Earth	63	0.085	0.166	
NVA of DEM	63	0.084	0.165	
VVA of Bare Earth	45	0.064		0.105
VVA of DEM	45	0.065		0.108

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

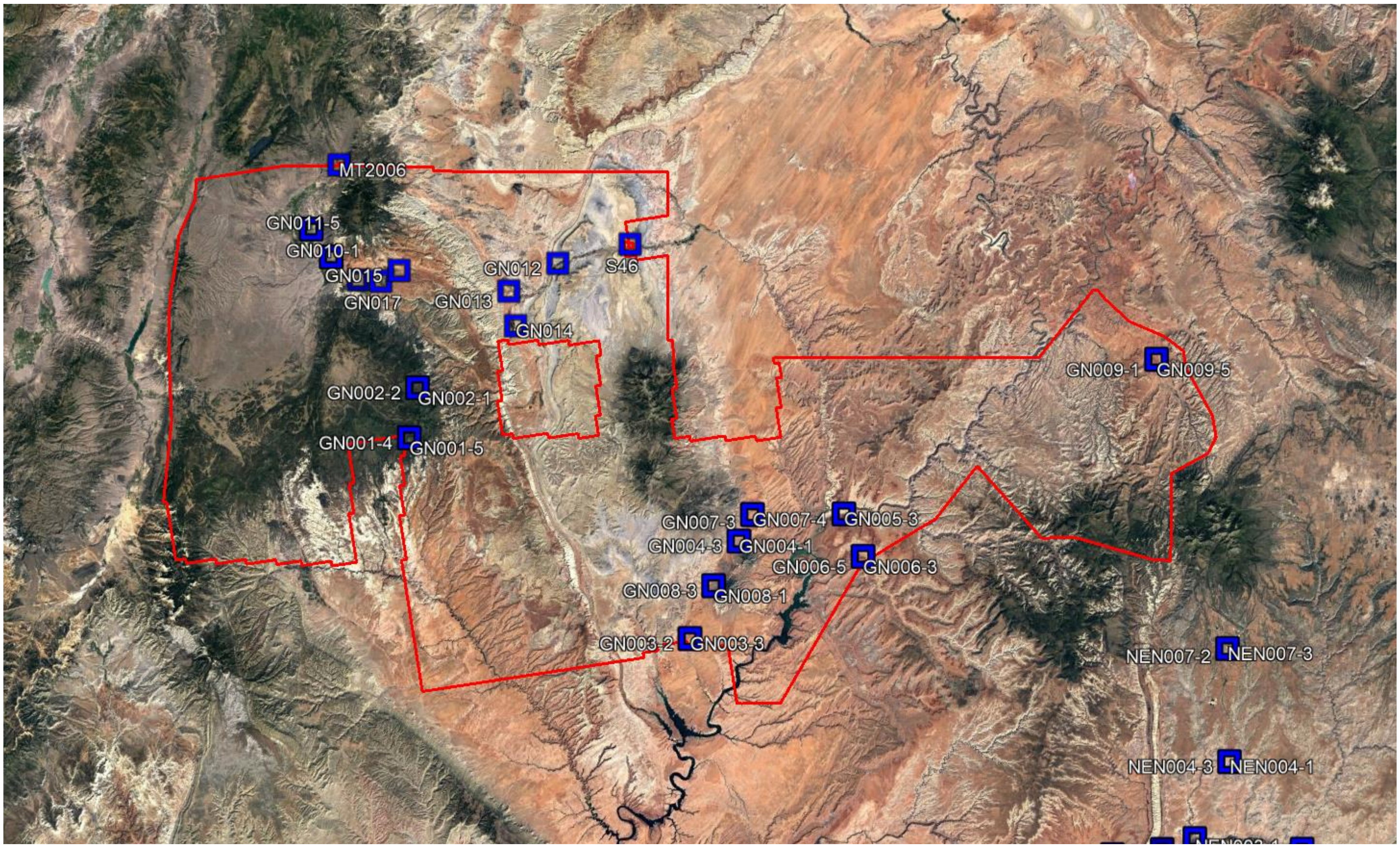


Figure 5: Non-vegetated Check Point Distribution

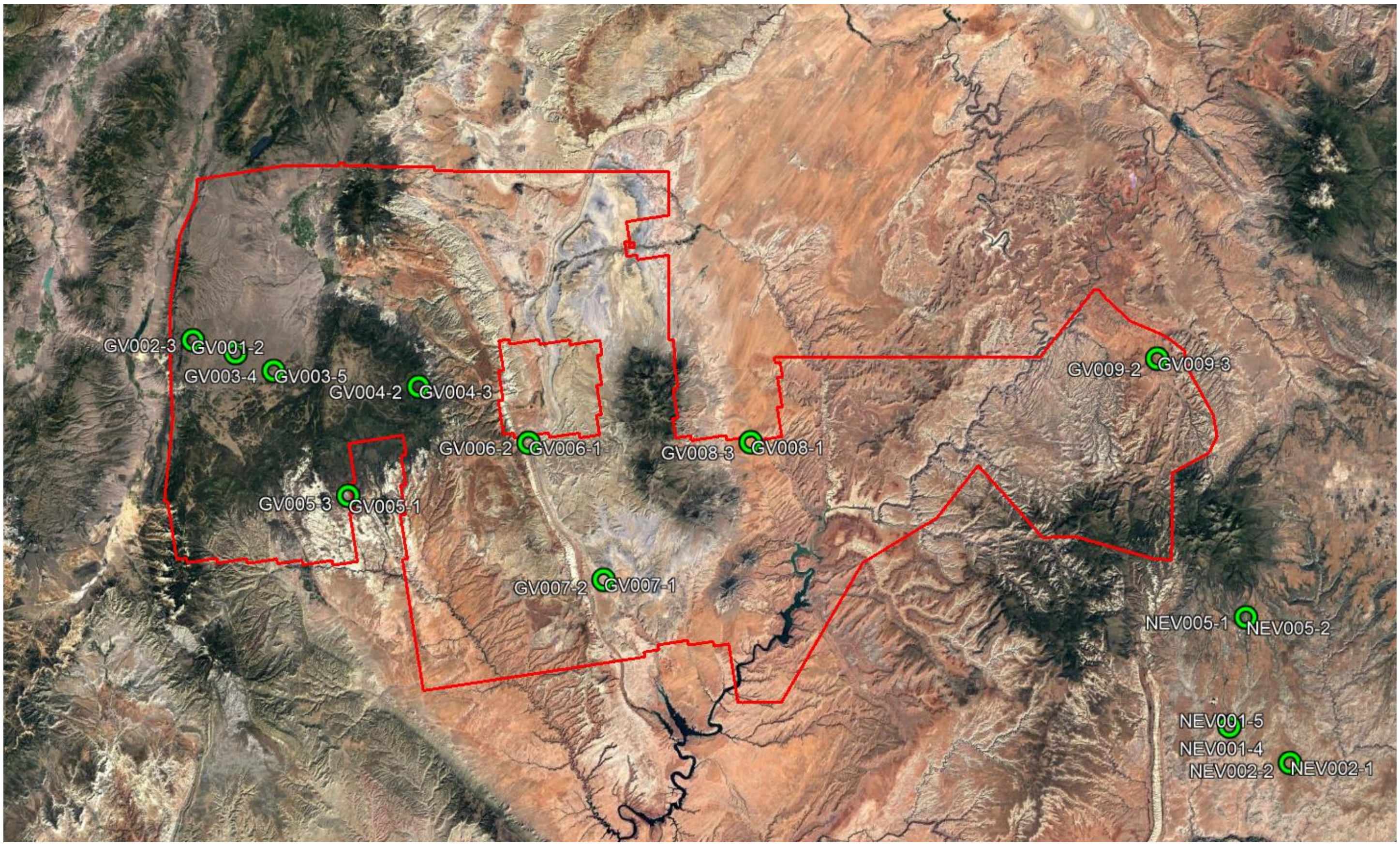


Figure 6: Vegetated Check Point Distribution

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.