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## AGRC Southern Utah Lidar (QL2 Block1) 312020335

# Lidar Report

October, 2020

### EXECUTIVE SUMMARY

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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 ~2019mi<sup>2</sup> was completed on May 27<sup>th</sup>, 2020.

The Optech Galaxy PRIME 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  $\leq 4$  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.

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## 1.0 INTRODUCTION

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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

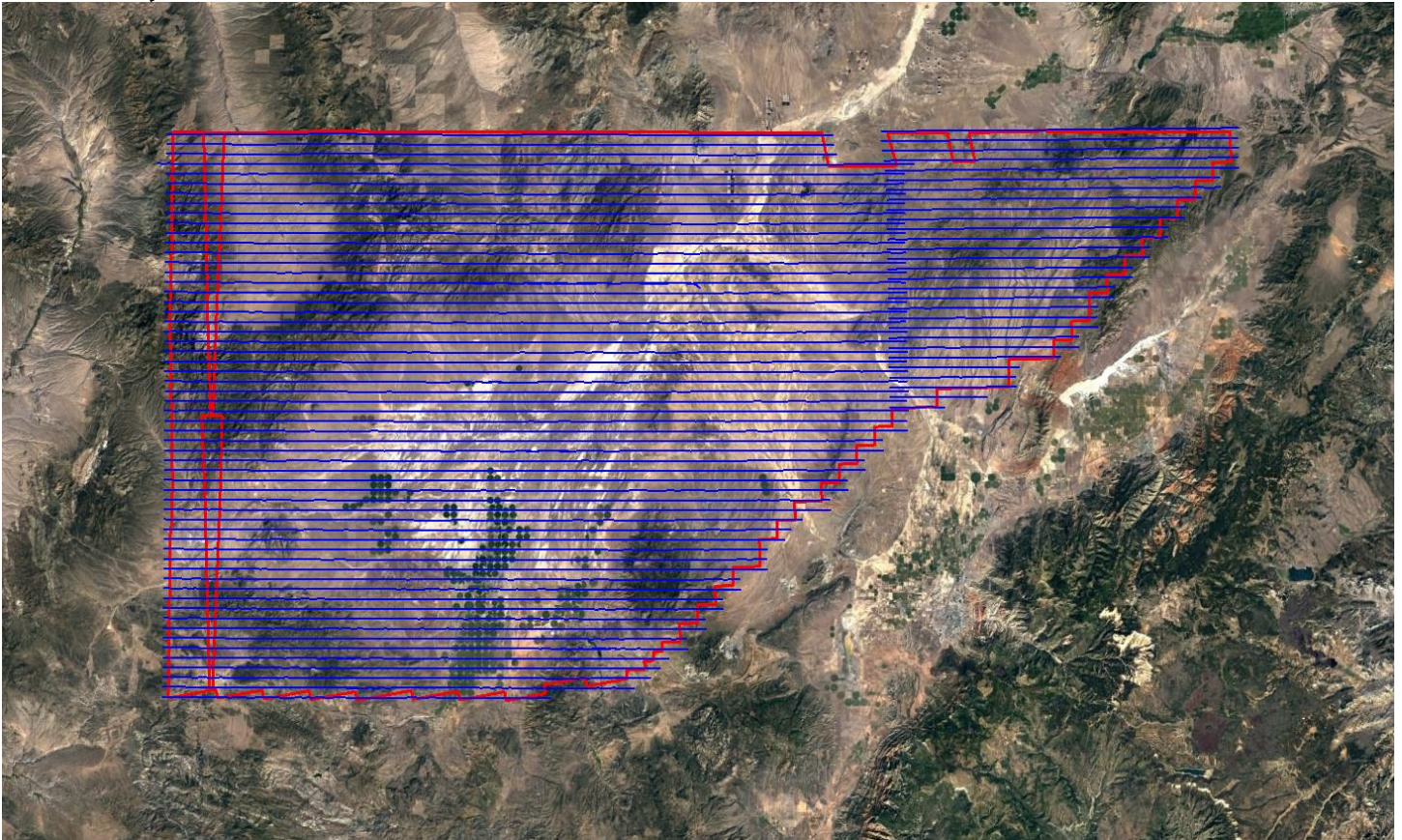


Figure 1: DPA and Trajectories As-Flown

## 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 Block1 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	Optech Galaxy PRIME
Flying Height (AGL) (m)	1600
Air Speed (kts)	120
Field of View (degrees)	46
Overlap (%)	20
Pulse Rate (kHz)	300
Scan Rate (Hz)	55.6
Laser Footprint (m)	0.24
Multi-Pulse	Yes
Point Spacing (m)	0.55
Point Density (pls/m <sup>2</sup> )	3.3
Swath Width (m)	1358

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 nine (9) 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)
5/7/2020	Optech Galaxy PRIME	5060410	-	20200507A_5060410	1.5	12:57:34	18:19:04
5/10/2020	Optech Galaxy PRIME	5060410	-	20200510A_5060410	1.7	12:09:52	17:35:10
5/11/2020	Optech Galaxy PRIME	5060410	-	20200511A_5060410	1.5	11:50:29	16:20:59
5/13/2020	Optech Galaxy PRIME	5060410	-	20200513A_5060410	1.5	11:57:37	16:51:40
5/14/2020	Optech Galaxy PRIME	5060410	-	20200514A_5060410	1.6	11:58:33	17:27:29
5/15/2020	Optech Galaxy PRIME	5060410	-	20200515A_5060410	1.4	12:00:41	16:59:57
5/15/2020	Optech Galaxy PRIME	5060410	-	20200515B_5060410	1.8	18:16:13	19:50:50
5/16/2020	Optech Galaxy PRIME	5060410	-	20200516A_5060410	1.6	12:02:12	17:54:08
5/27/2020	Optech Galaxy PRIME	5060410	-	20200527A_5060410	1.4	13:02:06	14:28:37

Table 2: Collection Date Time by Mission



Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
<b>ECHO</b>	CORS	AI8817	37 54 55.90473	114 15 51.24324	1684.960
<b>NVPI</b>	CORS	DM7135	37 56 13.34653	114 27 03.10105	1794.204
<b>NVSV</b>	CORS	DL6904	38 55 00.49290	114 24 09.60595	1776.758
<b>SGU1</b>	CORS	DN7504	37 06 47.48130	113 34 13.02325	895.565

Table 3: GNSS Reference Station Coordinates

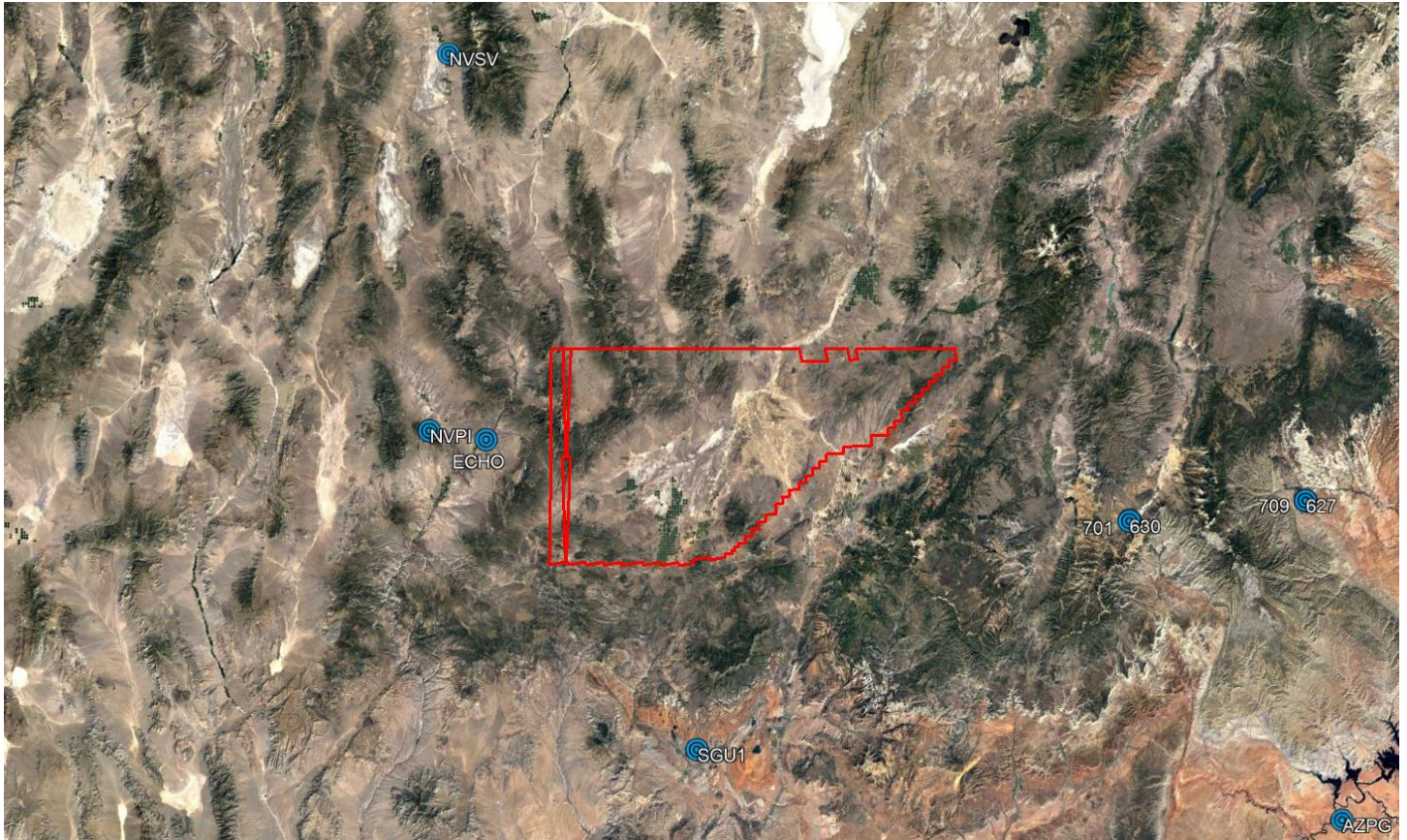


Figure 2: GNSS Reference Stations



### 3.0 PROCESSING

#### 3.1 Introduction

The GNSS/IMU data was post-processed using Applanix POSPac MMS software to create Smoothed Best Estimate Trajectory (SBET) file(s). The SBET was then combined with the laser range measurements in Optech LMS 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 Optech LMS 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	27,874,365,674
Aggregate Nominal Pulse Spacing (m)	0.47
Aggregate Nominal Pulse Density (pls/m <sup>2</sup> )	4.6
Aggregate Nominal Pulse Spacing (ft)	1.53
Aggregate Nominal Pulse Density (pls/ft <sup>2</sup> )	0.4

Table 4: Point Cloud Statistics

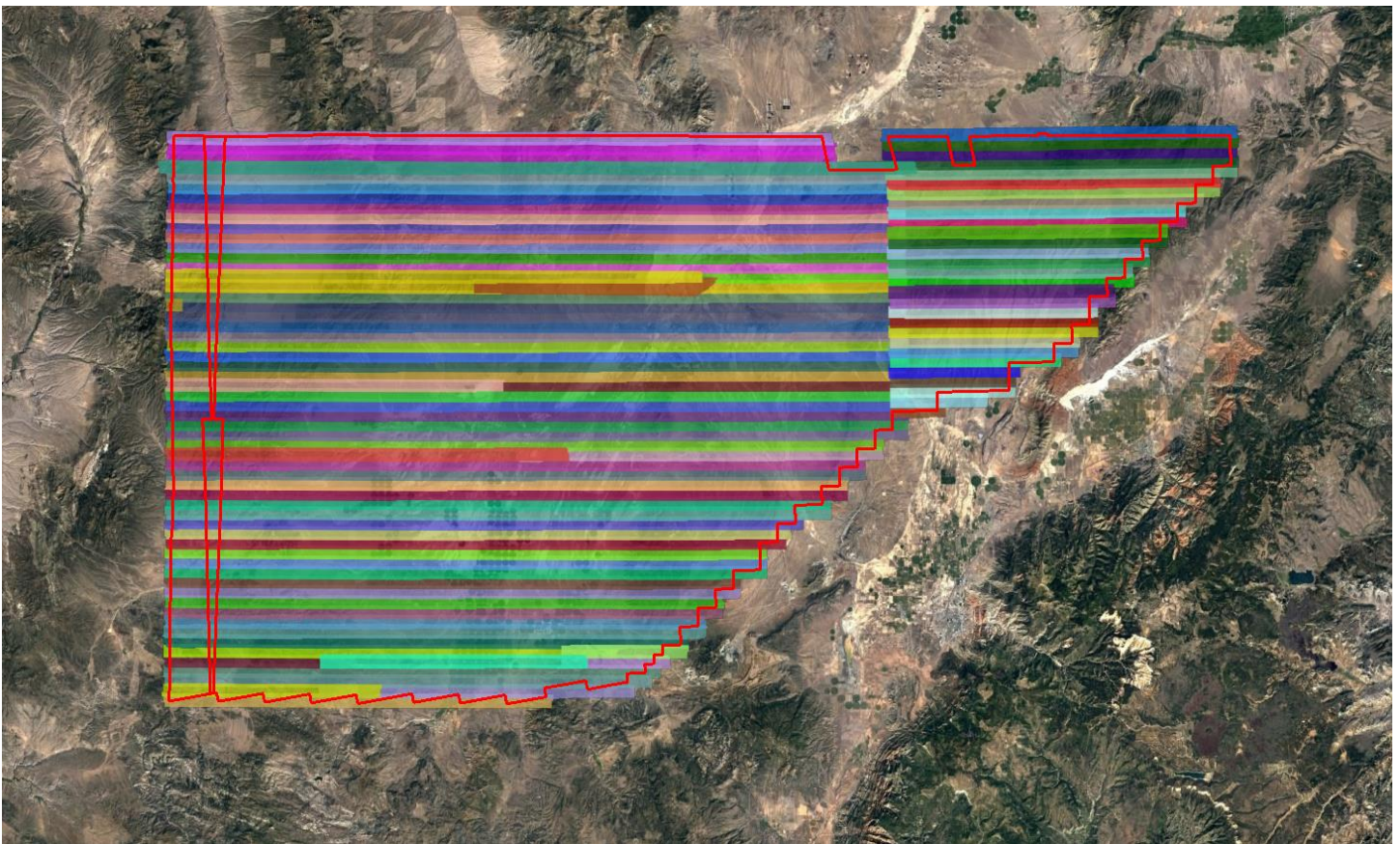


Figure 3: Raw Point Cloud Coverage

### 3.2 Coordinate Reference Systems

**Horizontal Datum:** North American Datum of 1983 (2011)  
**Projection:** Universal Transverse Mercator Zone 11 North  
**Vertical Datum:** North American Vertical Datum of 1988  
**Geoid Model:** Geoid12B  
**Units:** Meters

**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 Optech LMS 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



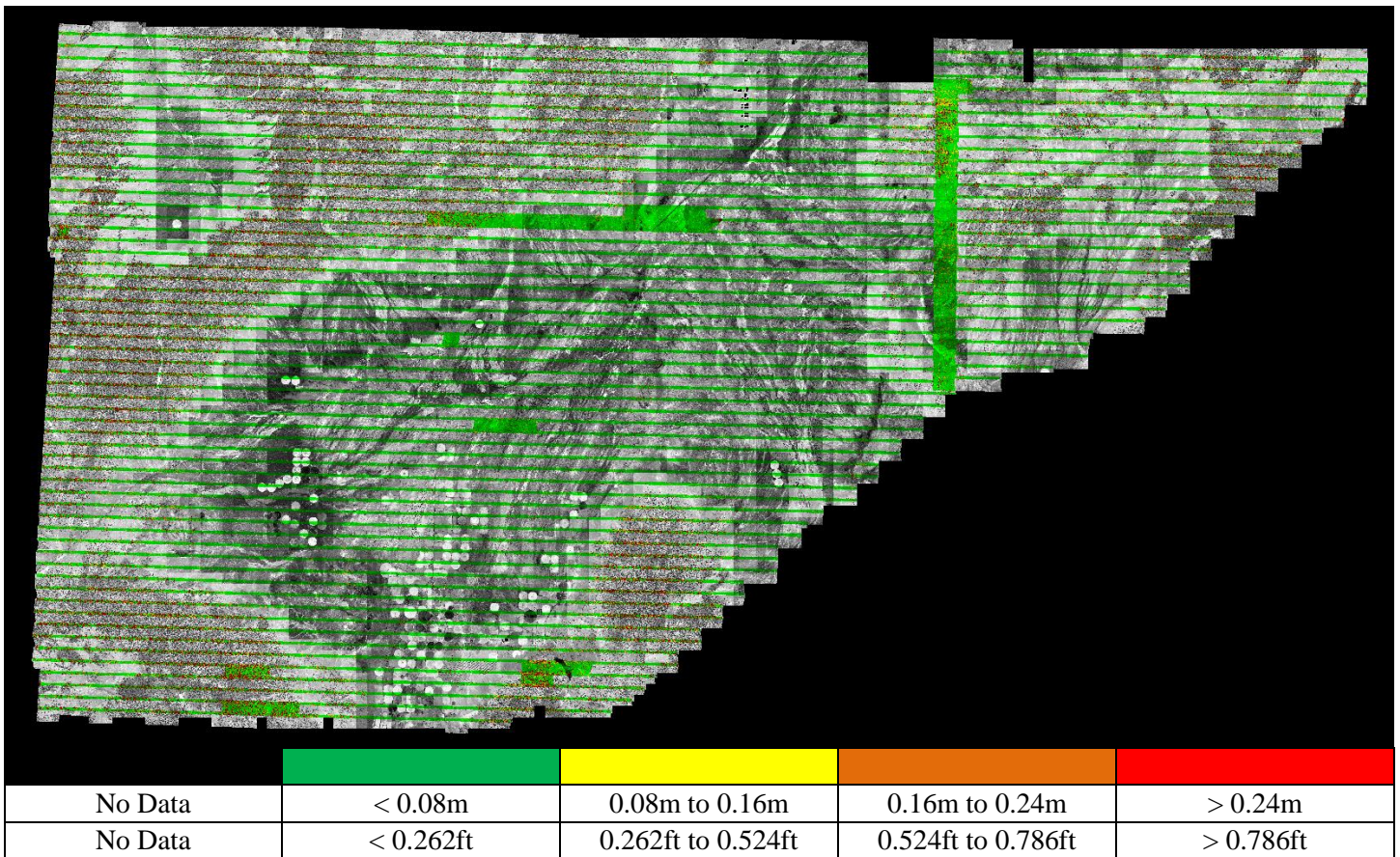


Figure 4: Swath Separation Images

Line	X	Y	Z	Line	X	Y	Z	Line	X	Y	Z
52	-	-	0.014	87	-	-	0.008	119	0.008	0.094	0.009
53	-	-	0.009	88	-	-	0.008	120	0.015	0.015	0.008
54	0.006	0.154	0.008	89	-	-	0.008	121	-	-	0.010
55	0.003	0.065	0.010	90	-	-	0.008	122	-	-	0.009
56	-	-	0.011	91	-	-	0.007	123	-	-	0.009
57	0.018	0.057	0.012	92	-	-	0.012	124	-	-	0.009
58	0.024	0.053	0.012	93	-	-	0.009	125	-	-	0.009
59	0.023	0.056	0.011	94	-	-	0.008	126	-	-	0.009
60	0.017	0.060	0.011	95	-	-	0.008	127	-	-	0.009
61	0.007	0.061	0.010	96	-	-	0.007	128	-	-	0.009
62	0.048	0.012	0.010	97	-	-	0.008	129	-	-	0.009
63	0.029	0.029	0.009	98	-	-	0.009	130	-	-	0.009
64	0.021	0.030	0.010	99	0.025	0.007	0.009	131	-	-	0.012
65	-	-	0.009	100	0.025	0.007	0.008	132	-	-	0.010
66	0.003	0.035	0.009	101	0.012	0.012	0.008	133	-	-	0.009
67	-	-	0.009	102	0.008	0.009	0.008	134	-	-	0.009
68	-	-	0.009	103	-	-	0.009	135	-	-	0.008
71	0.005	0.006	0.011	104	-	-	0.007	136	-	-	0.010
72	0.010	0.022	0.012	105	-	-	0.008	137	-	-	0.012
73	0.015	0.017	0.012	106	-	-	0.008	138	-	-	0.011
74	0.015	0.019	0.012	107	0.005	0.069	0.008	139	-	-	0.009
75	0.012	0.019	0.011	108	0.005	0.069	0.009	140	-	-	0.009



<b>76</b>	0.013	0.012	0.010	<b>109</b>	-	-	0.009	<b>141</b>	-	-	0.007
<b>77</b>	0.011	0.022	0.010	<b>110</b>	-	-	0.009	<b>142</b>	-	-	0.008
<b>78</b>	0.047	0.047	0.009	<b>111</b>	-	-	0.010	<b>143</b>	-	-	0.008
<b>79</b>	0.045	0.044	0.009	<b>112</b>	0.001	0.036	0.010	<b>144</b>	-	-	0.008
<b>80</b>	0.031	0.025	0.009	<b>113</b>	0.001	0.036	0.010	<b>145</b>	-	-	0.007
<b>81</b>	0.034	0.001	0.009	<b>114</b>	-	-	0.011	<b>146</b>	-	-	0.008
<b>82</b>	-	-	0.010	<b>115</b>	0.001	0.003	0.001	<b>147</b>	-	-	0.009
<b>83</b>	-	-	0.009	<b>116</b>	0.007	0.007	0.008	<b>148</b>	-	-	0.012
<b>84</b>	-	-	0.012	<b>117</b>	-	-	0.008	<b>149</b>	-	-	0.015
<b>85</b>	-	-	0.011	<b>118</b>	0.009	0.138	0.009	<b>338</b>	0.001	0.003	0.001

Table 6: Average Magnitudes by Line (Meters)

Category	X	Y	Z
<b>Average Magnitude</b>	0.019	0.035	0.009
<b>RMS Values</b>	0.031	0.061	0.012
<b>Maximum Values</b>	0.104	0.160	0.143
<b>Observation Weight</b>	333.0	333.0	124205.0

Table 7: Internal Observation Statistics (Meters)

Category	Mismatch
<b>Average 3D Mismatch</b>	0.00884
<b>Average XY Mismatch</b>	0.05083
<b>Average Z Mismatch</b>	0.00872

Table 8: Overall Relative Accuracy (Meters)

Category	Observations
<b>Section Lines</b>	61,194
<b>Roof Lines</b>	166

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
<b>Flag</b>	Overlap	Overage points lying within overlapping areas of two or more swaths
<b>Flag</b>	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 fifty-nine (59) check points (29 NVA + 30 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
@ 95 <sup>th</sup> Percentile	≤0.300	≤0.984

Table 11: Absolute Accuracy Requirements

Broad Land Cover Type	# of Points	RMSEz	95% Confidence Level	95th Percentile
<b>NVA of Point Cloud</b>	29	0.064	0.126	
<b>NVA of Bare Earth</b>	29	0.065	0.127	
<b>NVA of DEM</b>	29	0.059	0.115	
<b>VVA of Bare Earth</b>	30	0.088		0.177
<b>VVA of DEM</b>	30	0.047		0.104

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



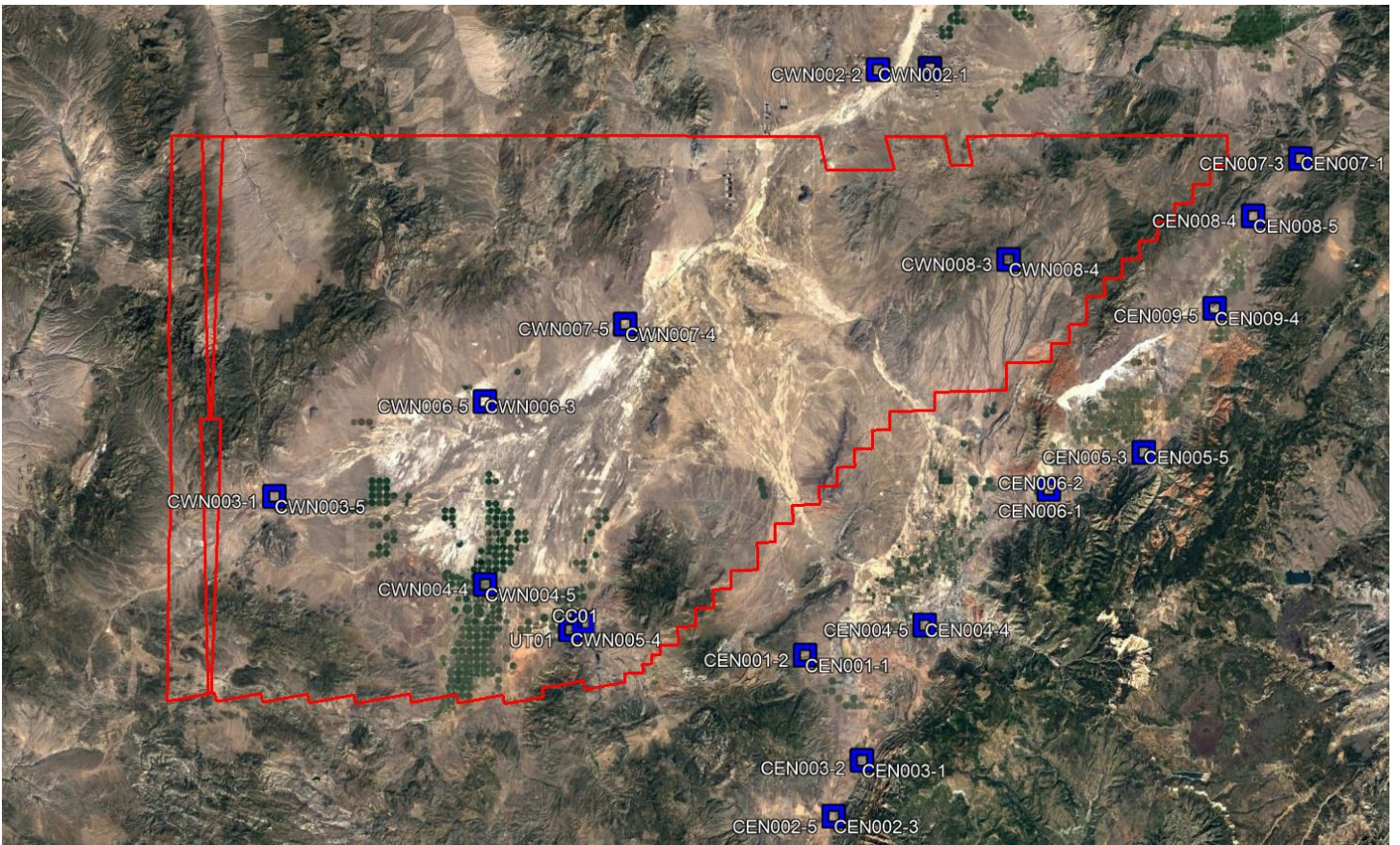


Figure 5: Non-vegetated Check Point Distribution

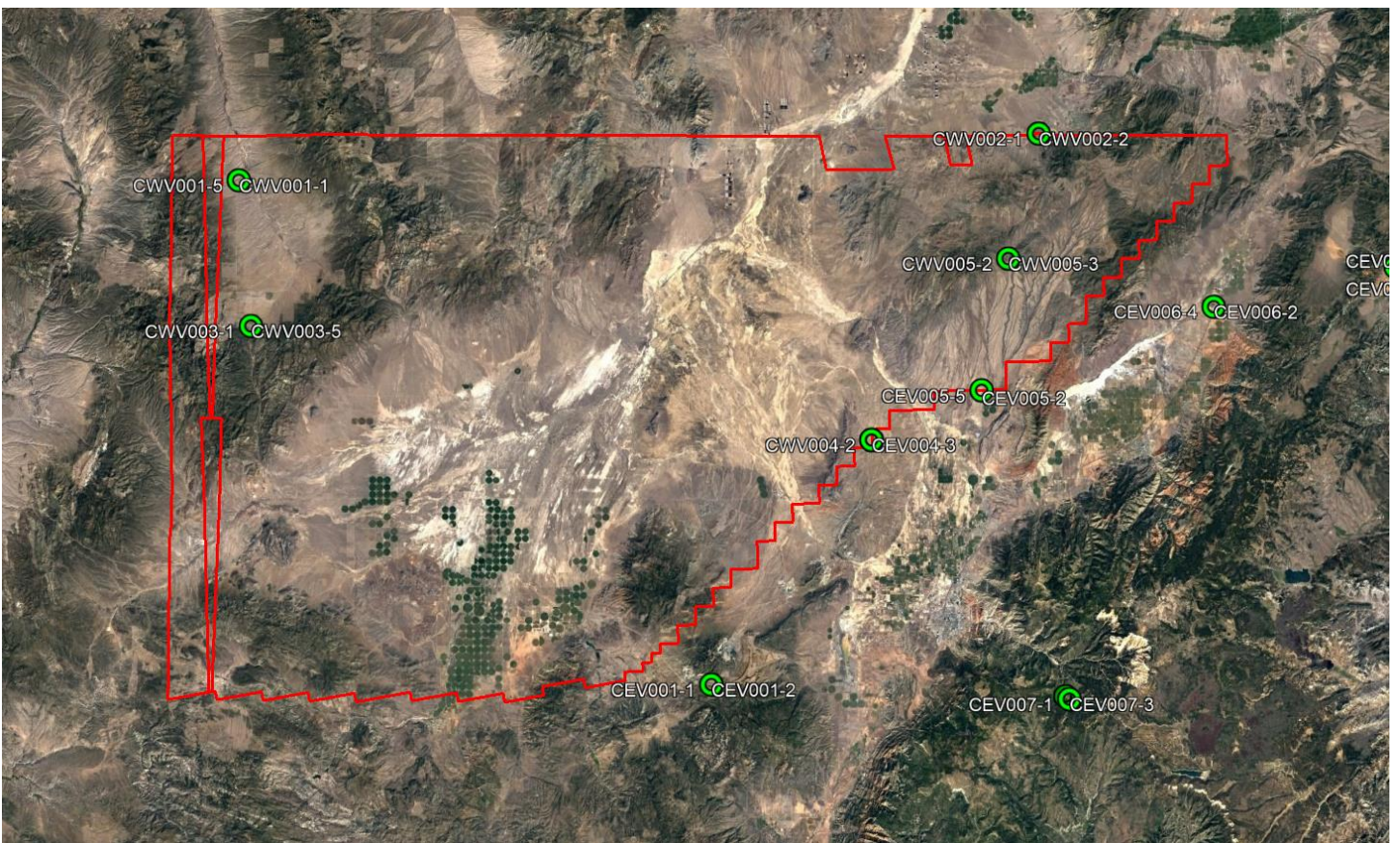


Figure 6: Vegetated Check Point Distribution



## 4.0 PRODUCT GENERATION

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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.