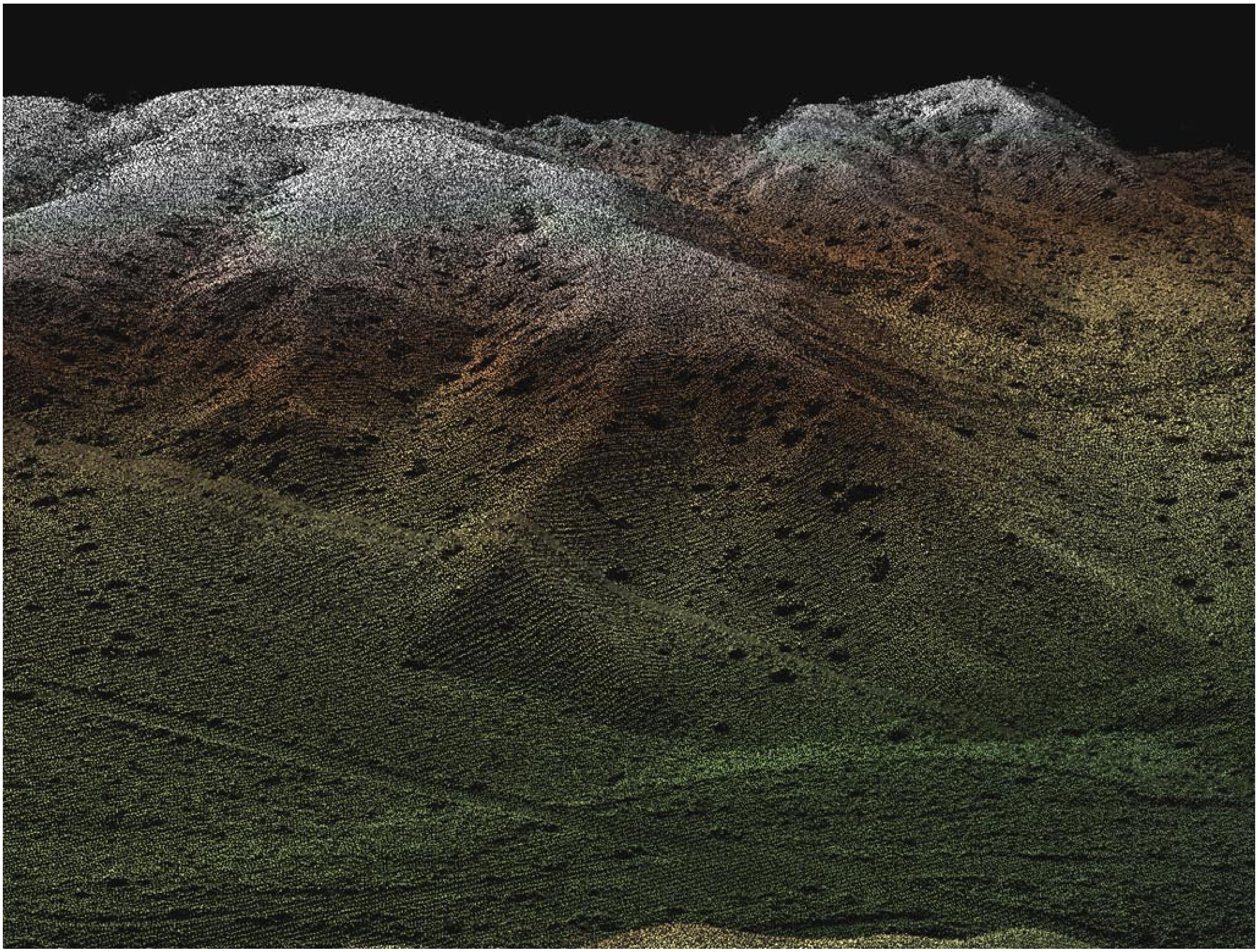
LiDAR DATA COLLECTION

NYE COUNTY, NEVADA

October 19 - 25, 2010



aero-graphics

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LiDAR Data Collection
Nye County, Nevada

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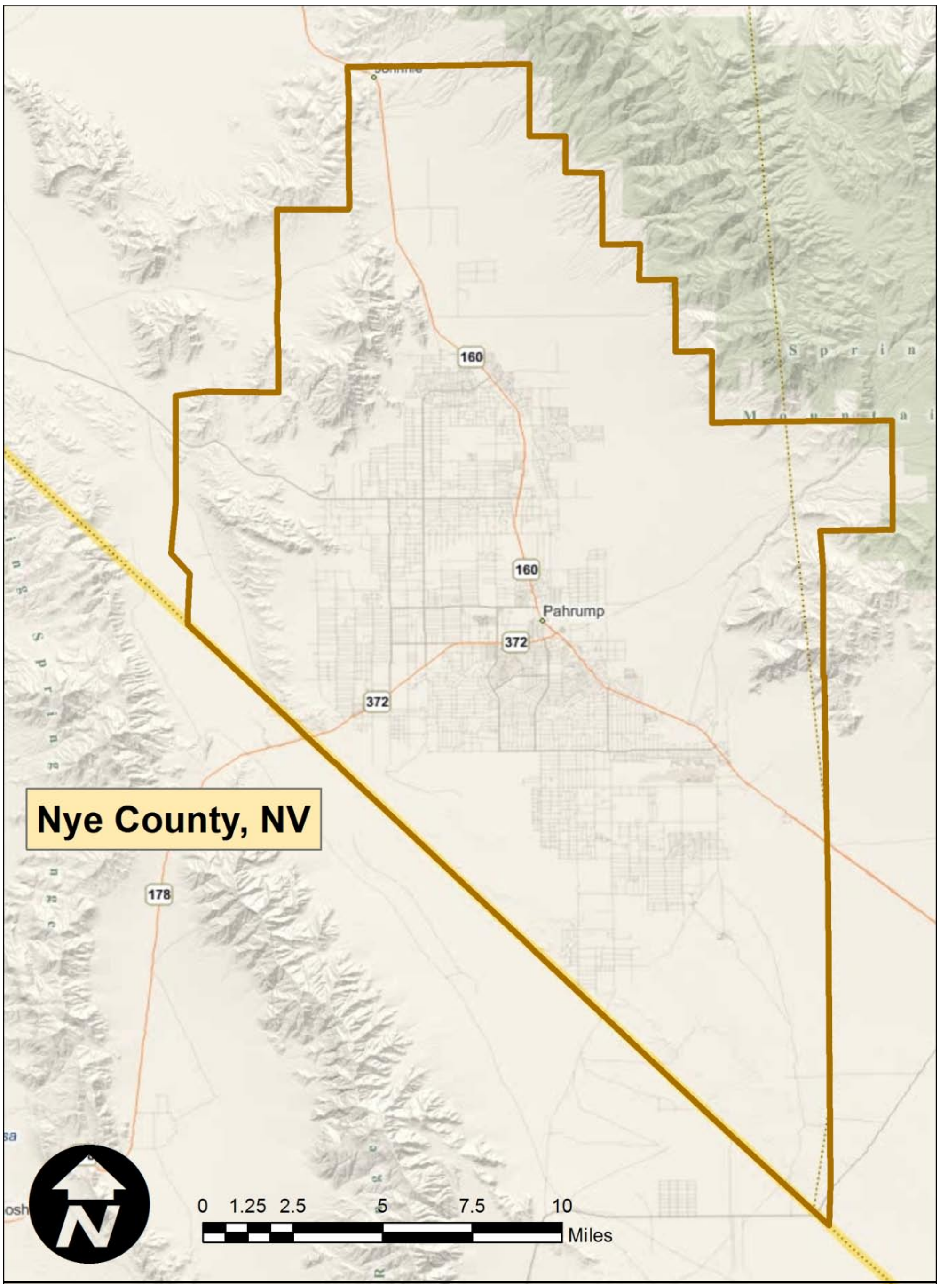
1. Overview

Between October 19 and 25, 2010, Aero-Graphics acquired LiDAR data over a portion of the Pahrump Valley in Nye County, Nevada. The acquisition covers roughly 350 square miles (224,000 acres).

Exhibit 1: *Nye County project boundary*



2. Acquisition

2.1 Airborne Acquisition – Equipment and Methodology

LiDAR acquisition of Nye County was performed with an Optech ALTM Orion sensor. Aero-Graphics flew at an average altitude of 5000 ft AGL (above ground level) and made appropriate adjustments to compensate for topographic relief. The PRF (pulse rate frequency) used for collection was 70 kHz, scan frequency of 34 Hz, and scan angle of +/- 16° from the nadir position (full scan angle 32°). The ALTM Orion features roll compensation that adjusts the mirror to maintain the full scan angle integrity in relation to nadir, even when less than perfect weather conditions push the sensor off nadir. Acquisition was performed with a 30% side lap and yielded 2.7 points per square meter throughout the project boundary. The Optech ALTM Orion is capable of receiving up to four range measurements, including 1st, 2nd, 3rd, and last returns for every pulse sent from the system.

Exhibit 2: *Summary of flight parameters*

Altitude (ft AGL)	Overlap (%)	Speed (kts)	PRF (kHz)	Scan Frequency (Hz)	Scan Angle ° (full)
5000	30	105	70	34	32

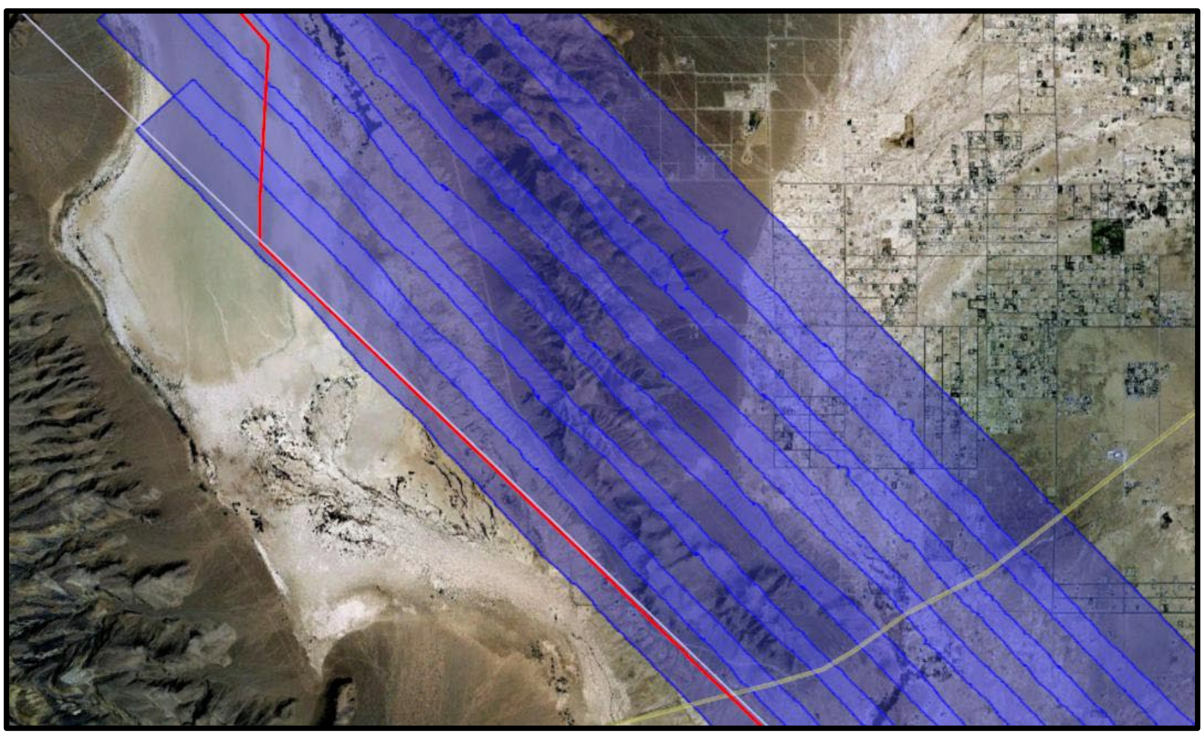
PPM^2 (nominal)	Post spacing Down Track (m)	Post Spacing Cross Track (m)
1.48	.79	.85

The ALTM Orion is also equipped with a GPS/IMU unit that continually records the XYZ position and roll, pitch and yaw attitude of the plane throughout the flight. This information allows us to correct laser return data positions that may have been thrown off by the plane's natural movement.

Exhibit 3: *The acquisition platform for the Nye County area was a turbo charged Cessna 206. Our 206 has been customized for LiDAR and other airborne sensors with an upgraded power system and avionics. The stability of the Cessna 206 is ideal for LiDAR collection.*

The ALTM Orion LiDAR sensor is equipped with ALTM-Nav Flight Management System Software. Not only is ALTM-Nav used to guide the airborne mission in flight, but our office flight planning is performed using a combination of Nav and traditional flight planning practices. The smooth transition from flight planning to aerial operations eliminates discrepancies between the flight plan and what is actually acquired. The use of ALTM-Nav helps ensure an accurate and consistent acquisition mission with real-time quality assurance while still airborne. The system operator can monitor the point density and swath during the mission to confirm adequate coverage within the area of interest, as shown in **Exhibit 4.**

__Exhibit 4:__ *Real time swath data for Nye County was recorded and viewed real-time by the operator.*



2.2 Ground Survey – Equipment and Methodology

Aero-Graphics used the following survey data to differentially correct the aircraft's trajectory data and to ensure that the LiDAR data maintained its true geographic integrity.

2.2.1 Base Stations

Using CORS base stations at strategic points in the project area, with data collected during the time of the LiDAR mission, we used SmartBase and IN-Fusion processing in Applanix's POSPac software to accurately correct the aircraft's real-time GPS trajectory.

Exhibit 5: *Ground bases and their geographic positions (NVCA pictured)*

Base Station	Datum: WGS84		WGS84
	Latitude	Longitude	Ellipsoid Height (m)
P092	36° 48' 15.09944"	-117° 24' 24.48965"	2157.075
STRI	36° 38' 40.63737"	-116° 20' 16.05764"	1029.850
P462	36° 04' 16.73864"	-116° 37' 43.35172"	1334.402
JOHN	36° 27' 31.73147"	-116° 05' 56.54980"	871.732
SHOS	35° 58' 16.84259"	-116° 17' 56.34720"	582.403
P621	35° 28' 21.93627"	-115° 32' 38.22173"	1420.493
NVPO	35° 57' 22.59945"	-115° 29' 44.18027"	2491.715
NVTP	36° 05' 57.02609"	-115° 19' 44.53418"	845.169
RUMP	36° 15' 24.86379"	-115° 52' 06.45511"	1406.135
NVBM	35° 58' 11.33363"	-115° 09' 27.05122"	712.509
NVLM	36° 04' 10.77090"	-114° 48' 47.54512"	362.062
NVCA	36° 13' 11.20744"	-115° 10' 19.40543"	645.440
POIN	36° 34' 46.71430"	-116° 07' 11.43060"	916.631
NOPE	35° 58' 10.02298"	-115° 59' 06.14366"	844.182

2.2.2 Ground Survey Control

Aero-Graphics collected the following static measurements, which allowed us to ensure project-specified accuracy on the final LiDAR and surface deliverables. This final accuracy is presented in section 4.2.

Exhibit 6: *Static ground survey measurements*

Survey Point	Datum: WGS84		WGS84
	Latitude	Longitude	Ellipsoid Height (m)
101	36° 18' 30.49604"	-116° 12' 00.29940"	743.290
102	36° 26' 15.22882"	-116° 04' 45.01687"	963.908
103	36° 27' 27.28202"	-116° 03' 15.32700"	1164.616
104	36° 20' 49.40859"	-116° 09' 10.08526"	845.192
105	36° 16' 22.40390"	-115° 47' 21.24197"	1930.270
106	35° 59' 24.56624"	-115° 50' 39.10145"	823.36°3
107	35° 58' 21.72956"	-115° 51' 28.37430"	792.023
108	36° 07' 22.20699"	-115° 51' 03.03923"	943.274
109	36° 13' 21.01085"	-116° 08' 39.21462"	732.234
110	36° 10' 08.10319"	-116° 06' 10.03367"	746.787
111	36° 08' 46.92338"	-115° 58' 22.23203"	778.590
112	36° 06' 09.44749"	-115° 56' 15.37731"	791.948
113	36° 12' 18.99699"	-115° 59' 55.32842"	772.635
114	36° 16' 42.73803"	-116° 04' 09.83328"	757.202
115	36° 16' 37.63921"	-115° 59' 34.84013"	798.174
116	36° 12' 08.81053"	-115° 53' 55.06077"	981.946
117	36° 17' 01.49838"	-115° 49' 45.20731"	1599.414
118	36° 15' 36.26461"	-115° 52' 21.31820"	1379.137
119	36° 05' 22.67584"	-115° 59' 45.84473"	754.365
120	36° 13' 35.99410"	-116° 03' 01.71940"	753.292
121	36° 20' 07.44038"	-116° 02' 43.99399"	809.836
122	36° 20' 13.72529"	-115° 56' 56.87523"	1181.242
123	36° 20' 14.36403"	-115° 59' 47.96077"	938.357
124	36° 23' 28.56244"	-116° 03' 58.36148"	934.222
125	36° 16' 38.45366"	-116° 08' 26.72190"	858.899
126	36° 14' 00.88167"	-115° 54' 50.36737"	1086.904
127	36° 08' 46.43725"	-115° 54' 11.66651"	814.309
128	36° 03' 33.70876"	-115° 53' 03.40215"	847.764
130	36° 24' 01.89377"	-116° 01' 57.09276"	1033.566
131	36° 21' 06.97469"	-116° 00' 15.15190"	964.672
132	36° 14' 18.02815"	-115° 58' 07.44470"	861.780
133	36° 09' 39.50689"	-116° 02' 32.88688"	748.421
134	36° 12' 17.71176"	-116° 05' 42.54584"	744.247
135	36° 21' 40.82237"	-116° 05' 35.24934"	962.343
1907BC	36° 12' 20.38605"	-115° 59' 14.50864"	785.232
PLS4957	36° 13' 29.57228"	-115° 59' 57.52899"	772.212

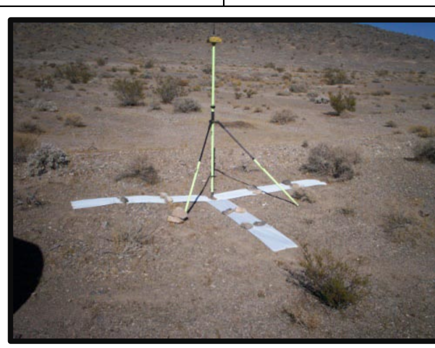
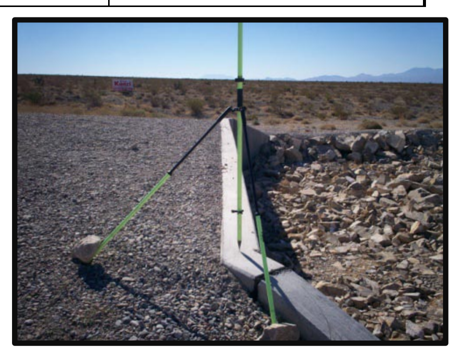
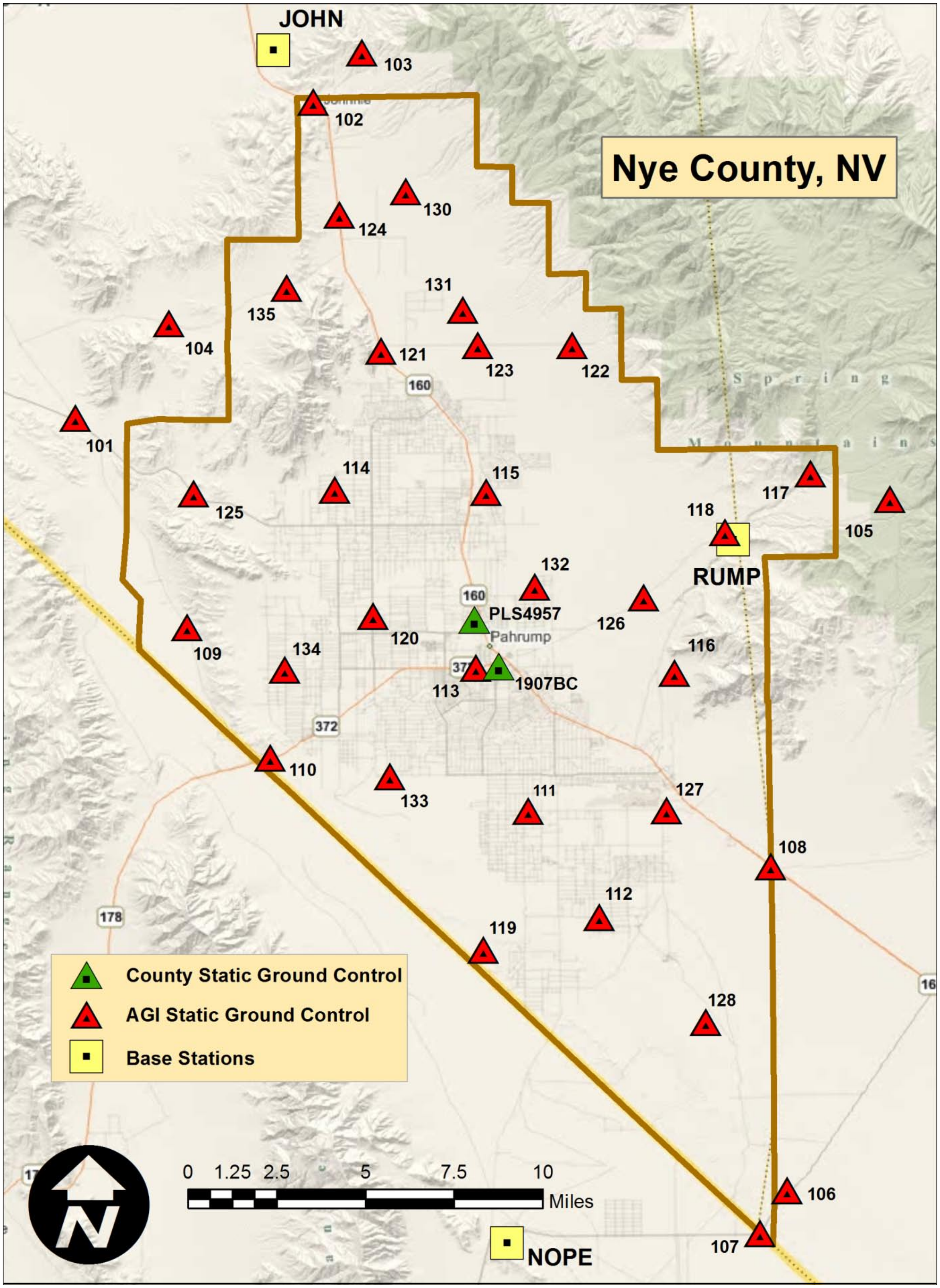




Exhibit 7: *AGI static ground control and CORS base locations for Nye County*



3. LiDAR Processing Workflow and Software

a. **Absolute Sensor Calibration.** The absolute sensor calibration is defined as the difference in roll, pitch, heading, and scale between the raw laser point cloud from the sensor and surveyed control points on the ground over two separate sites. **Software:** LiDAR Mapping Suite 1.0.

b. **Kinematic Air Point Processing.** Differentially corrected the 1-second airborne GPS positions with ground base stations; combined and refined the GPS positions with 1/200-second IMU (roll-pitch-yaw) data through development of a smoothed best estimate of trajectory (SBET). **Software:** Applanix POSPac 5.3 Service Pack 3.

c. **Raw LiDAR Point Processing.** Combined SBET with raw LiDAR range data; solved real-world position for each laser point; produced point cloud data by flight strip in ASPRS v1.2 .LAS format; output in WGS84 UTM Ellipsoid Heights. **Software:** LiDAR Mapping Suite 1.0.

d. **Relative Calibration.** Tested relative accuracy; performed relative calibration by correcting for roll, pitch, heading, and scale discrepancies between adjacent flightlines. Results presented in Section 4.1. **Software:** LiDAR Mapping Suite 1.0.

e. **Coordinate System Transformation.** Transformed all .LAS tiles from WGS84 UTM 11N Ellipsoid Heights into NAD83 Nevada Central State Plane Zone, adjusted for orthometric heights on NAVD88 (Geoid09). Integrity of the .LAS file format was maintained throughout the process. **Software:** Blue Marble Desktop 2.1.

f. **Tiling & Long/Short Filtering.** Cut data into project-specified tiles and filtered out grossly long and short returns. **Software:** FME 2011 for Oracle with Oracle 11g.

g. **Classification.** Ran classification algorithms on points in each tile; separated into ground, unclassified, high outliers and low outliers; revisited areas not completely classified automatically and manually corrected them. **Software:** TerraScan, FME 2011, GeoMedia Professional.

h. **QA/QC, Hydro-enforcement, and Contour Generation.** Using an iterative process, inspected and corrected misclassified points that could cause ground surface anomalies; added breaklines where required to more accurately model the terrain surface; and generated final 1- and 2-foot contours in DWG and ESRI Geodatabase format. **Software:** GeoMedia Professional, Intergraph Image Station, FME 2011 for Oracle.

i. **Absolute Accuracy Assessment.** Performed comparative tests that showed Z-differences between each static survey point and the laser point surface. Results presented in Section 4.2. **Software:** FME 2011, Oracle 11g.

j. **DEM Creation.** Generated 1-meter first-return DEMs and 1-meter ground surface DEMs in ESRI Raster Grid format, tiled according to project specifications. **Software:** FME 2011, Geospatial Data Abstraction Layer (GDAL), libLAS LiDAR Data Translation Toolset.

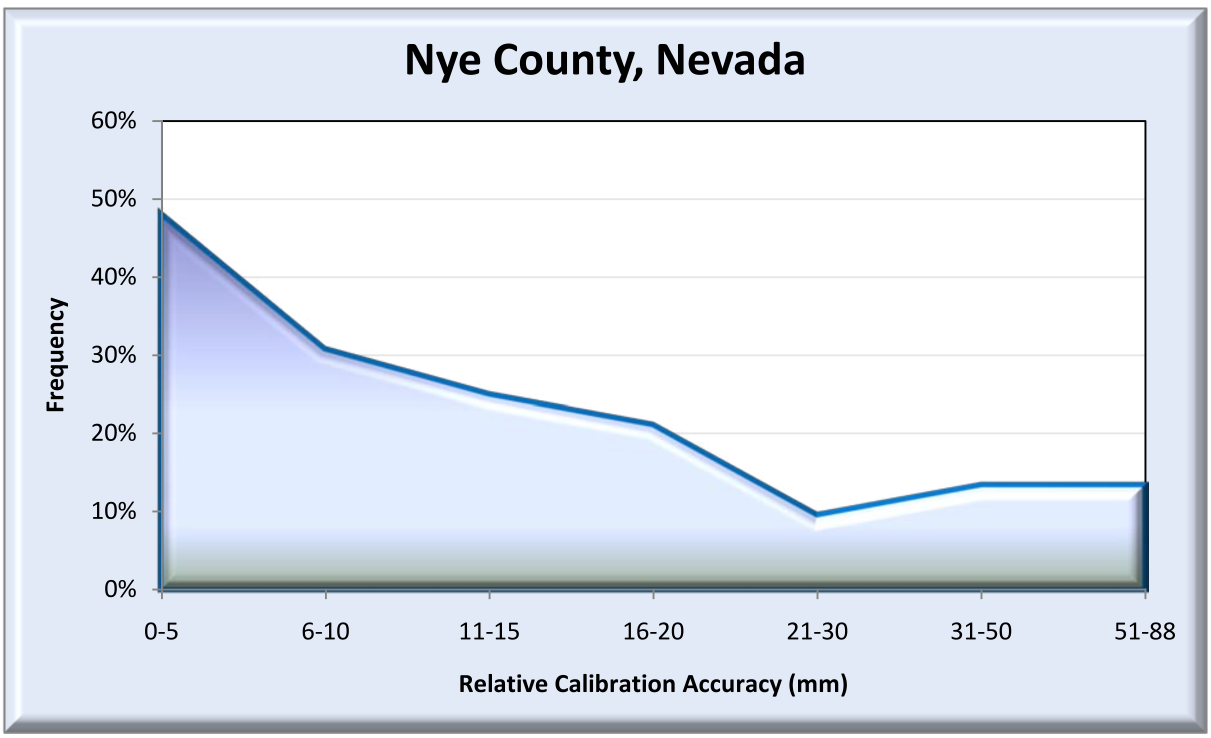
4. Results

4.1 Relative Calibration Accuracy Results

Relative accuracy statistics for Nye County are based on the comparison of 84 flightlines and over 2.7 billion points.

- Relative accuracy **average** of 17.5 mm
- Relative accuracy **median** of 11.1 mm

<u>Exhibit 8:</u> *Inter-flightline relative calibration accuracies, post-calibration. Demonstrates the percentage of compared points within a given accuracy range.*



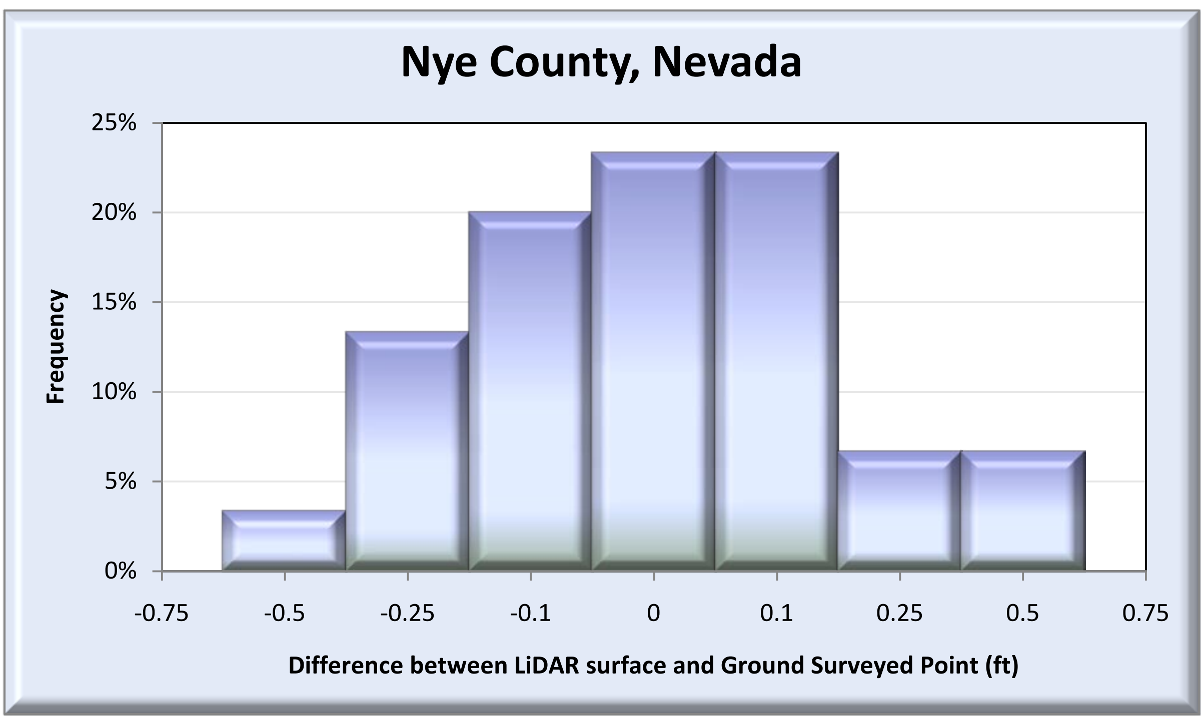
4.2 Absolute Accuracy

Absolute accuracy is defined as the elevation difference between ground surveyed static points and the elevation of the LiDAR surface at that same horizontal location. The statistics of the results are presented here.

Exhibit 9: *Absolute accuracy of the Nye County project*

Average Error = -0.001 ft	**RMSE = 0.191 ft**
Minimum Error = -0.468 ft	**σ = 0.194 ft**
Maximum Error = 0.455 ft	**2 σ = 0.388 ft**
Survey Sample Size: n = 30	

Exhibit 10: *Distribution of the errors between LiDAR surface and Ground Surveyed points. Demonstrates the percentage of compared points within a given accuracy range.*



4.3 Data Density

The goal for this project was to achieve a LiDAR point density of greater than one point per square meter. The acquisition mission achieved an actual average of 2.7 points per square meter.

***Exhibit 11:* Nye County – All returns** *Laser Point Density by Frequency, points/m^2. Demonstrates the percentage of compared points within a given density range*

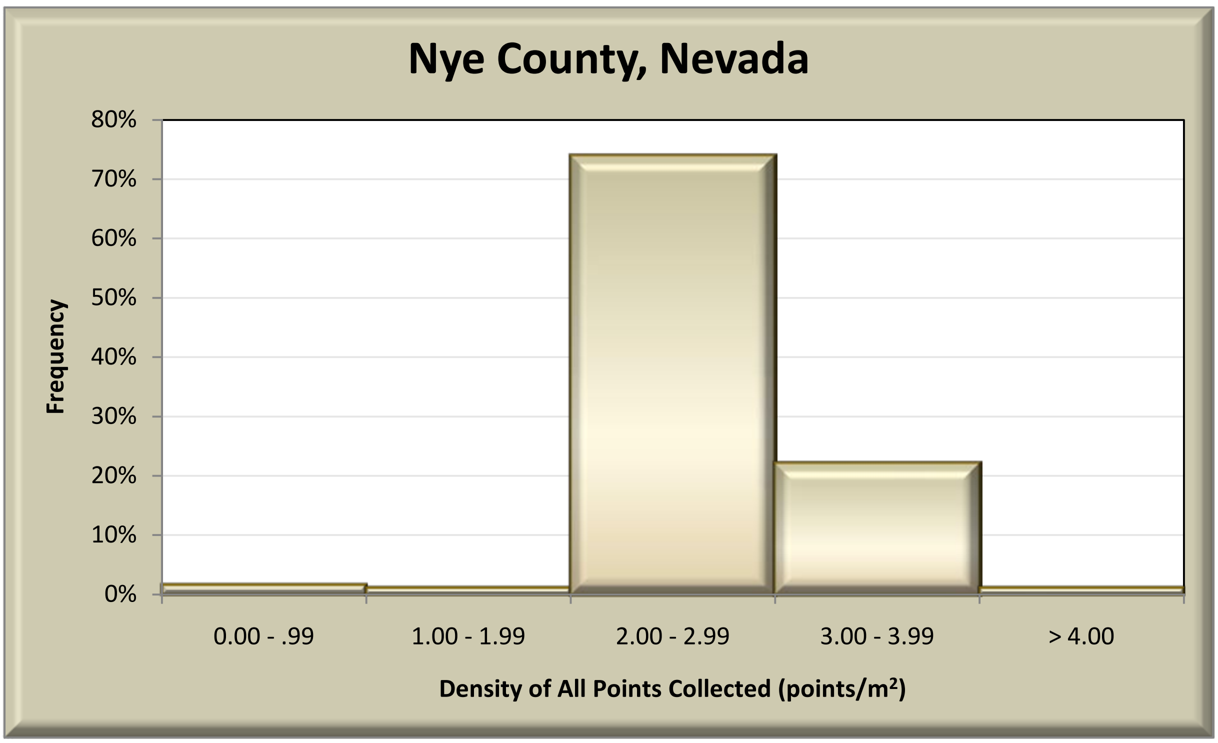
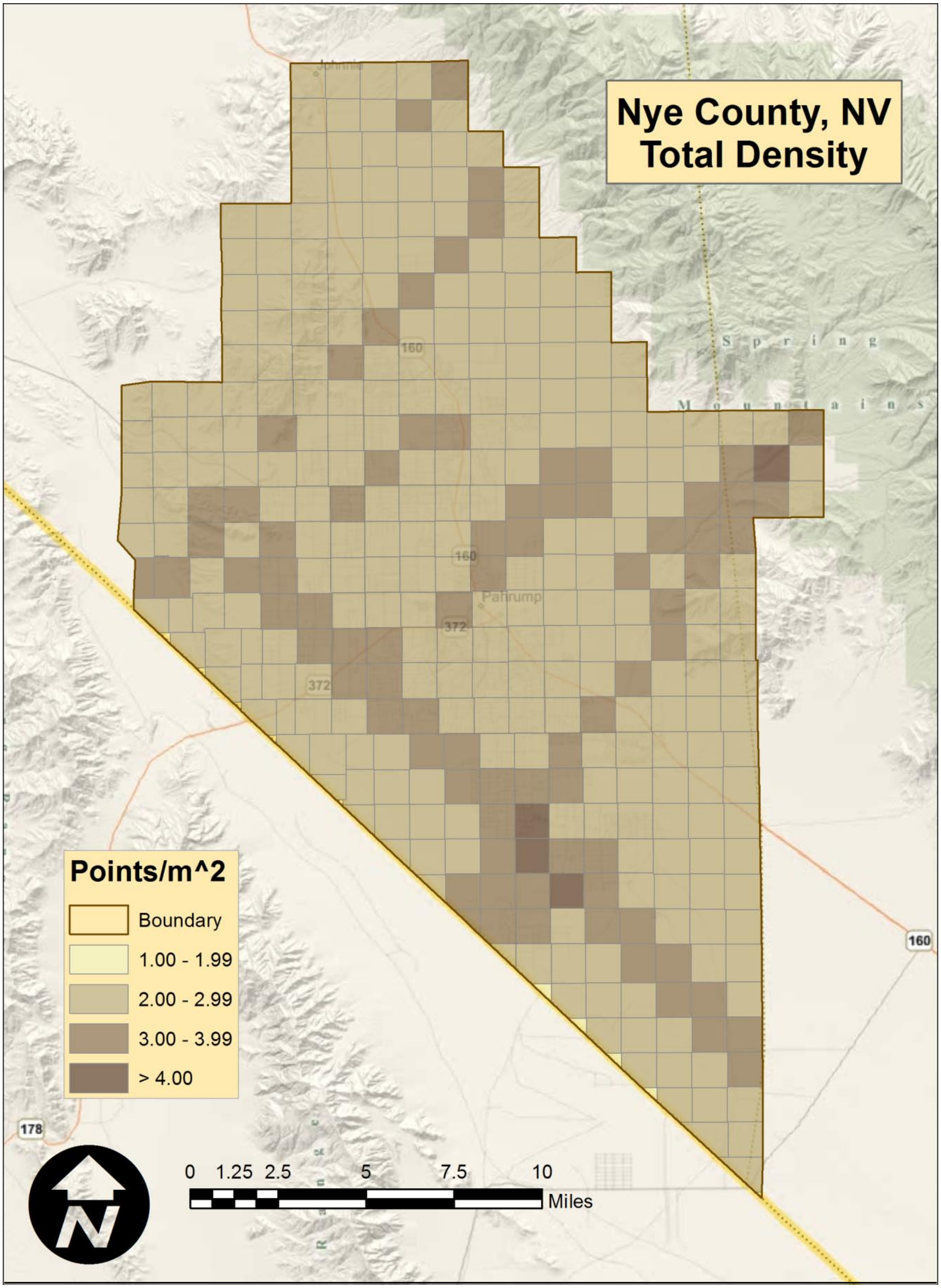


Exhibit 12: *Laser Point Density of All Returns by Tile, points/m²*



The following two exhibits show the density of **ground classified points**. Factors such as vegetation, water, and buildings will affect the density of points classified to the ground. For the Nye County project area, an average of 2.2 ground classified points per square meter was achieved.

***<u>Exhibit 13:</u>* Nye County - Ground Classified** *Laser Point Density by Frequency, points/m^2. Demonstrates the percentage of compared points within a given density range*

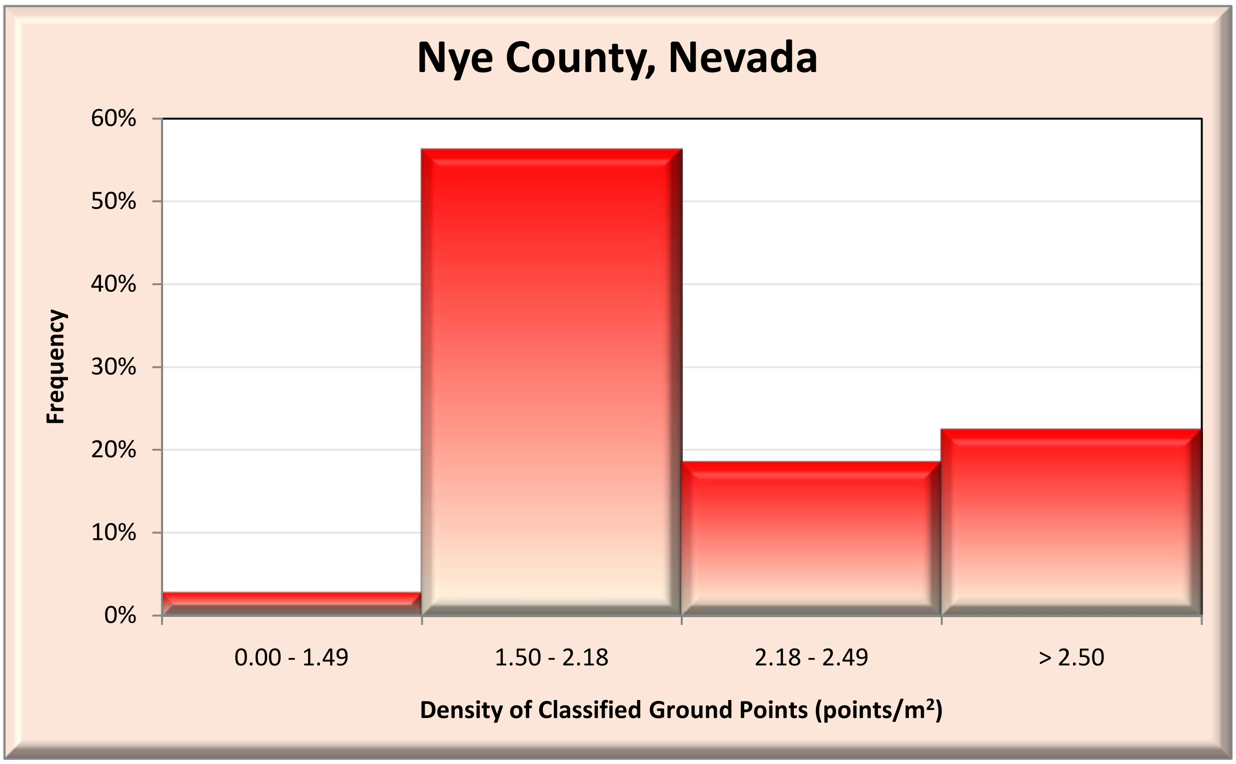
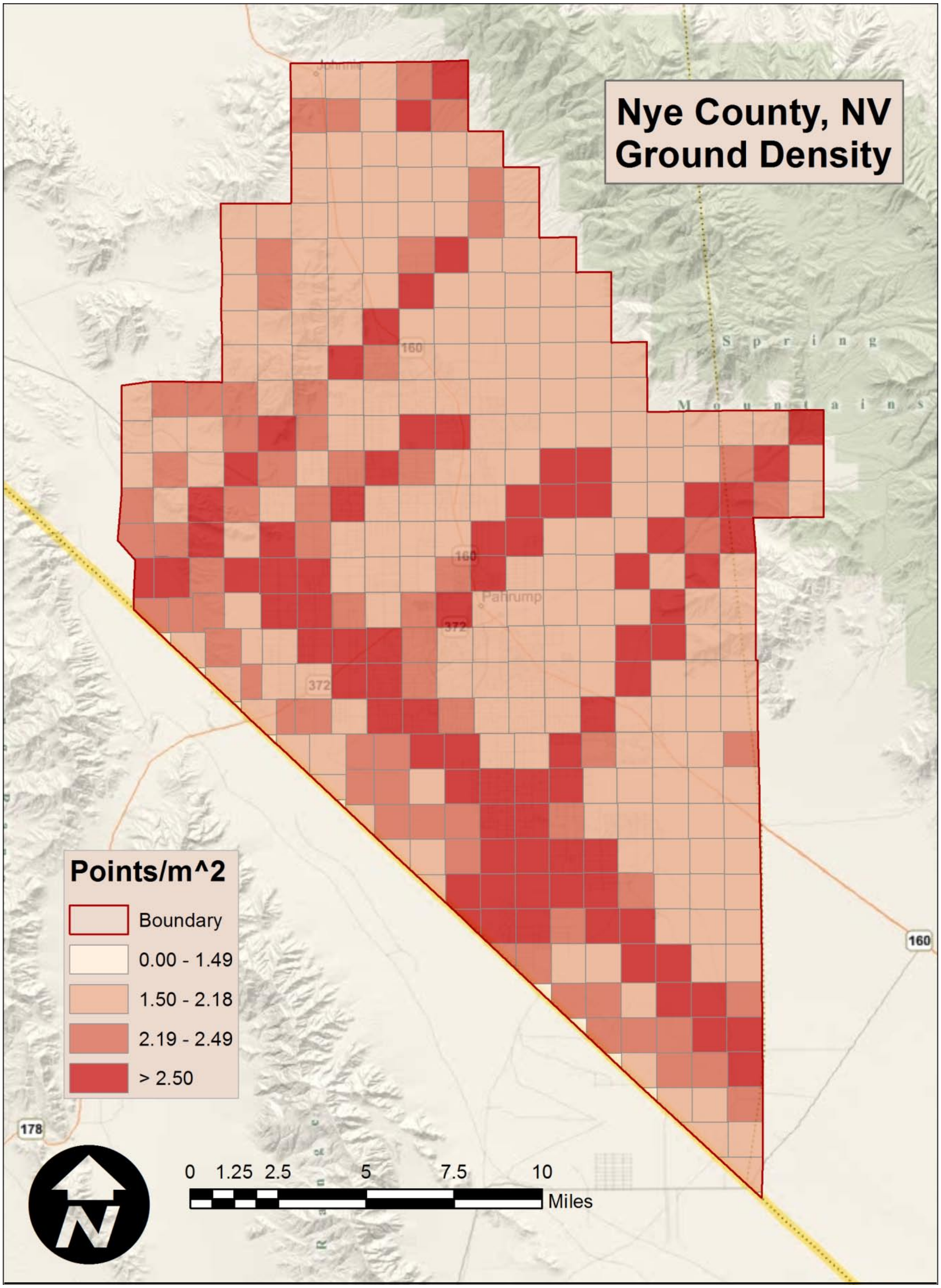


Exhibit 14: *Ground Classified Laser Point Density by Tile, points/m^2*



4.4 Data Density Summary

Nye County Project Area	Goal	Actual (mean)
Total Point Density:	**1 point/m^2**	**2.7 points/m^2**
Ground Classified Point Density:	**-------**	**2.2 points/m^2**

4.5 Projection, Datum, and Units

	Projection:	Nevada Central State Plane Zone
	Ellipsoid:	GRS80
Datum	**Vertical:**	NAVD88 Geoid 09
	Horizontal:	NAD83
	Units:	US Foot

5. Deliverables

Point Data:	• Bare-earth classified laser returns in LAS 1.1 format
Vector Data:	• 1’ contours in DWG and ESRI Shapefile formats for the SW area • 2’ contours in DWG and ESRI Shapefile formats for the NE area • Breakline-enforced DTM in ASCII format for the entire area
Raster Data:	• Hydrologically-enforced ground surface DEMs in ESRI Raster Grid format at a 3’ cell size • First-return surface DEMs in ESRI Raster Grid format at a 3’ cell size
Report of Survey:	• Post-Deliverable Report including methodology, accuracy, and results

6. Selected Images

Exhibit 15: *Point cloud over a dry wash*

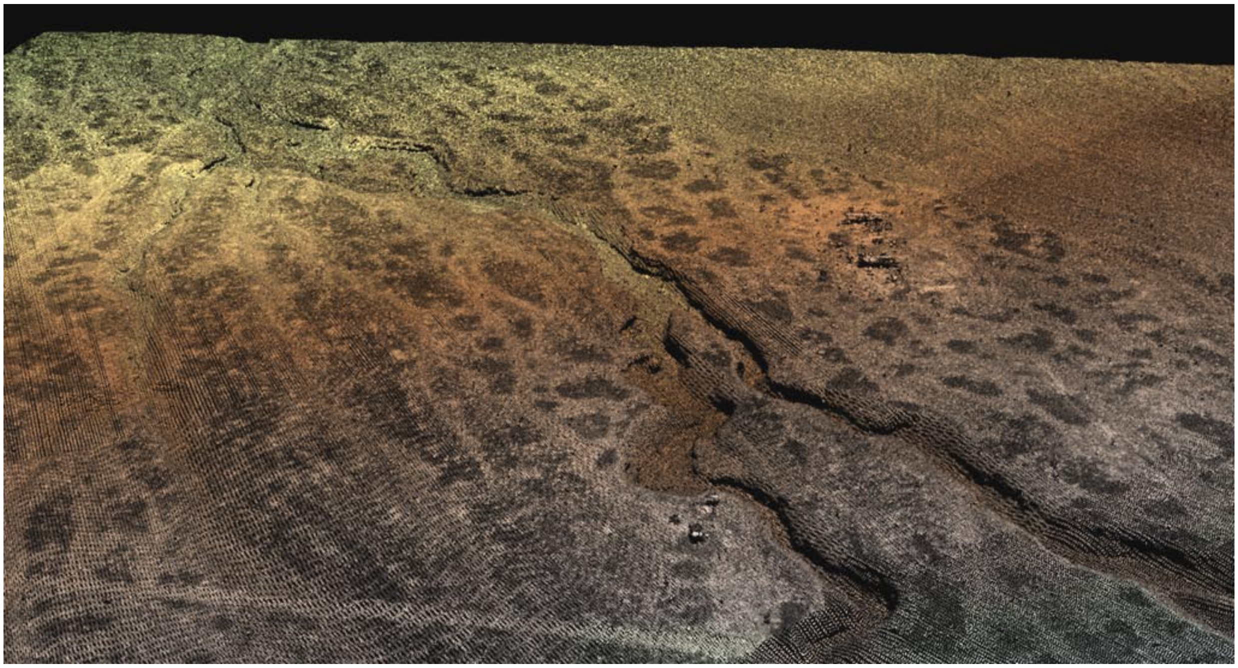


Exhibit 16: *Point cloud depicting Pahrump*