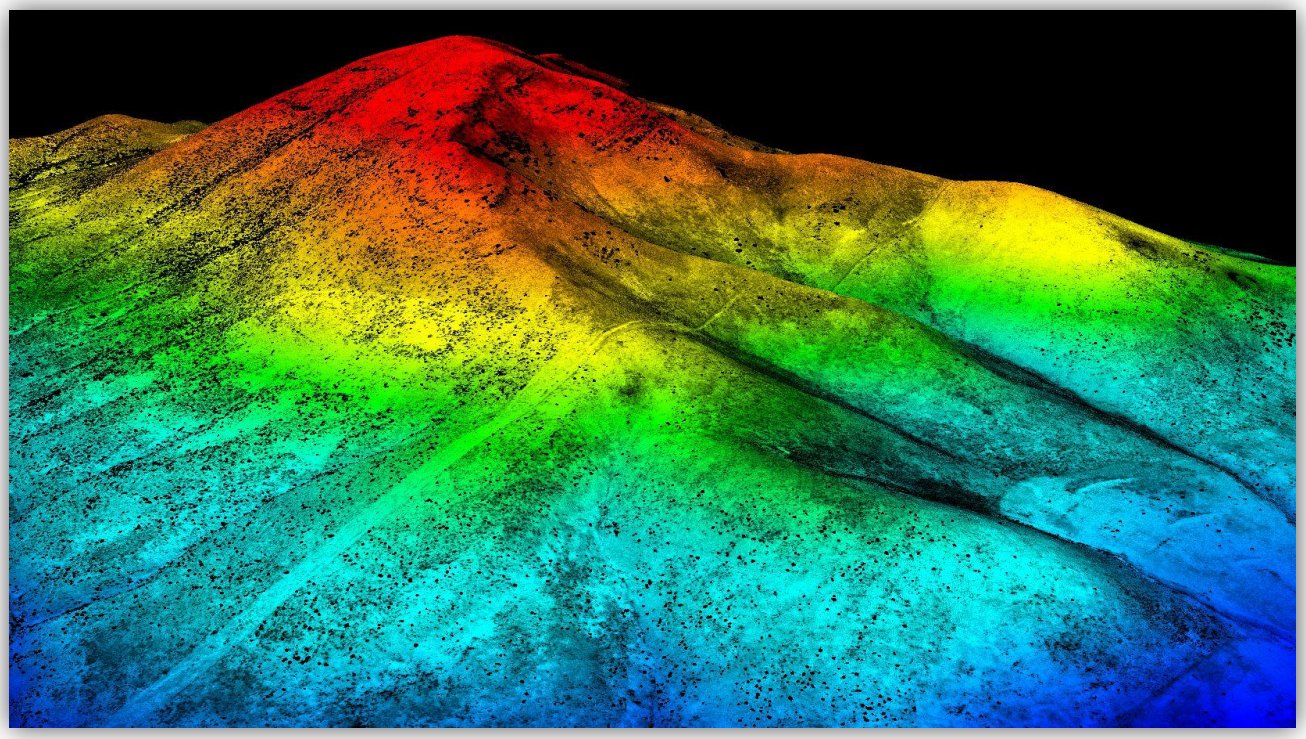
aero-graphics

FINAL PROJECT REPORT

WASHAKIE & WHITES VALLEY AERIAL SURVEY

BOX ELDER COUNTY, UTAH

April 15-16, 2017



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Final Project Report
Washakie & Whites Valley
Box Elder County, UT

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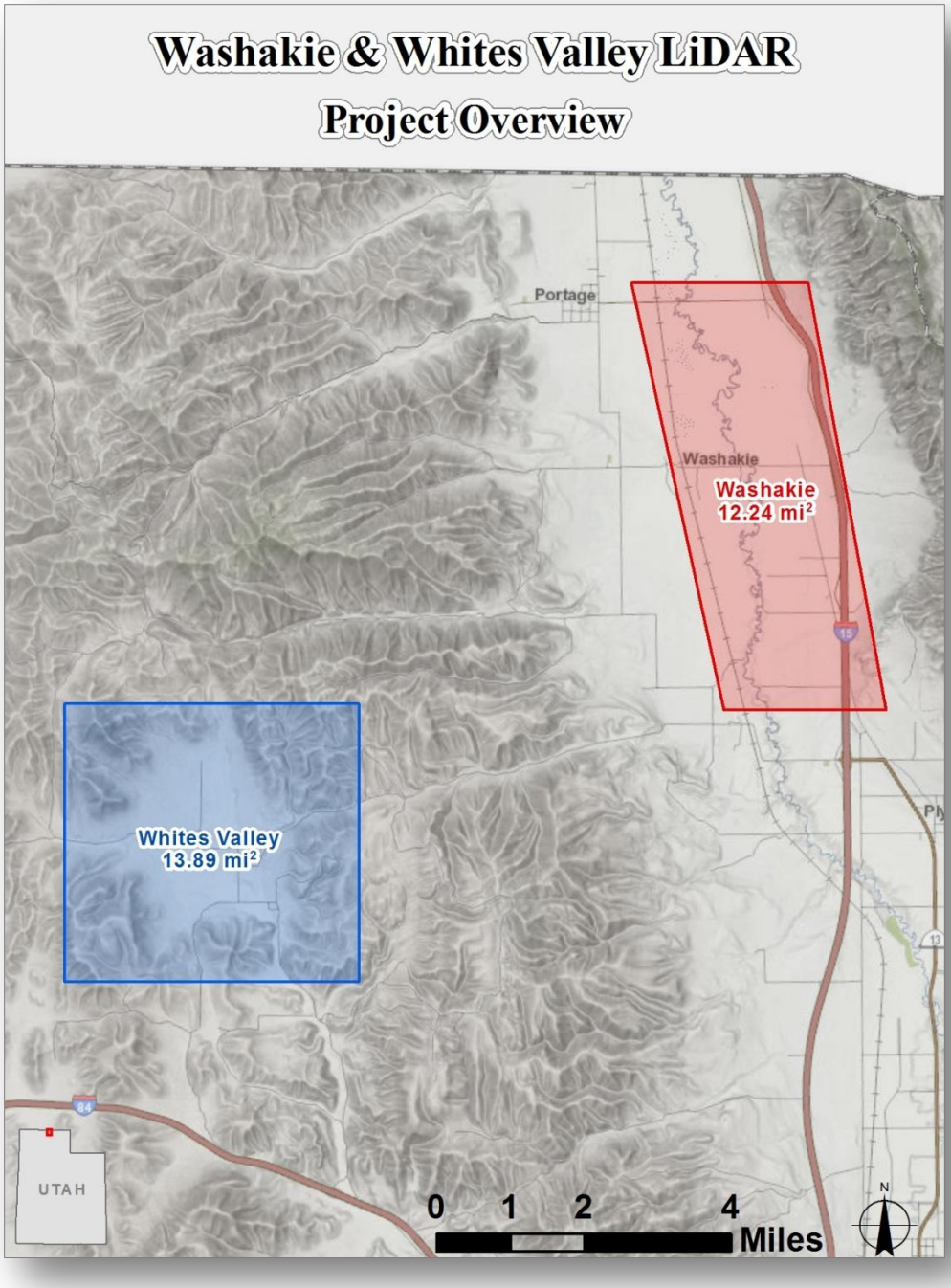
1. Overview

Aero-Graphics, Inc. was contracted by the State of Utah, Department of Technology Services, Division of Integrated Technology, Automated Geographic Reference Center (AGRC) and partners to acquire, process, and deliver aerial LiDAR data and derivative products that adhere to USGS Quality Level 1 LiDAR specifications. The project areas cover approximately 26.2 square miles and are located in Box Elder County, Utah.

Exhibit 1: *Washakie & Whites Valley project boundaries*



2. LiDAR Acquisition – Equipment and Methodology

LiDAR acquisition for the Washakie & Whites Valley project was performed on April 15 and 16, 2017, with an Optech ALTM Orion H300 LiDAR sensor. Aero-Graphics flew at an average altitude of 4,331 ft AGL (above ground level) and made appropriate adjustments to compensate for topographic relief. The PRF (pulse rate frequency) used for collection was 175 kHz, scan frequency 76.9 Hz, and scan angle +/- 6° from the nadir position (full scan angle 12°). LiDAR acquisition was performed with 30% overlap and yielded an average 13 points per square meter throughout the project areas.

Exhibit 2: *Summary of planned flight parameters*

Altitude (ft AGL)	Overlap (%)	Speed (kts)	PRF (kHz)	Scan Freq (Hz)	Scan Angle ° (full)
4,331	30	105	175	76.9	12

PPM^2 (mean)	Post spacing Cross Track (m)	Post Spacing Down Track (m)	Swath Width (m)	# Flightlines
11.68	0.35	0.35	277.48	61

Product Characterization Report

The Orion H300 can send/receive up to 300,000 pulses per second and is capable of receiving up to four range measurements, including 1st, 2nd, 3rd, and last returns for every pulse sent from the system. The Orion H300 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. It 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 Washakie & Whites Valley project was a turbocharged 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 H300 LiDAR sensor is equipped with FMS Planner Flight Management System Software, which is the latest release from Optech. Aero-Graphics utilizes FMS Planner to both plan the flight and guide the airborne mission while in flight. This smooth transition from flight planning to aerial operations eliminates discrepancies between the flight plan and the actual airborne mission. The use of FMS Planner 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: *Swath data for the Washakie & Whites Valley project was recorded and viewed real-time by the system operator.*

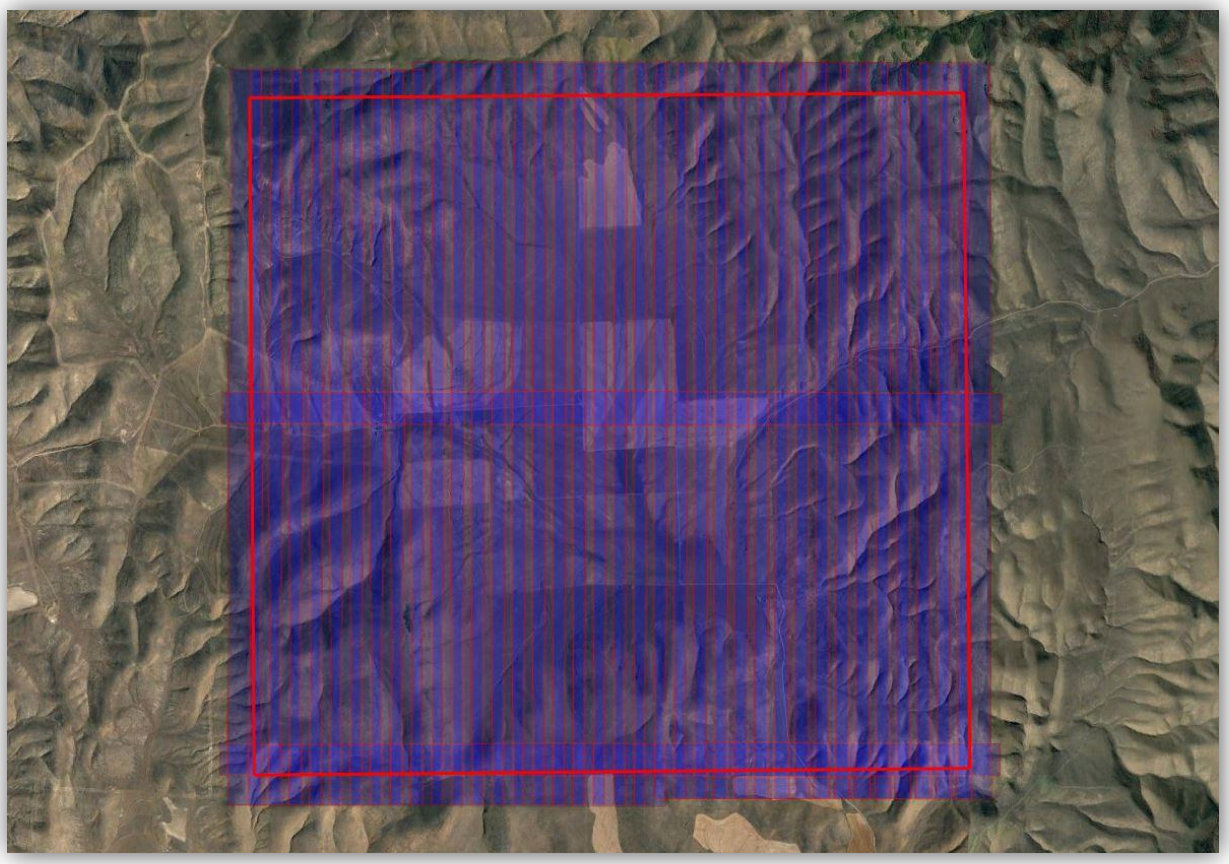
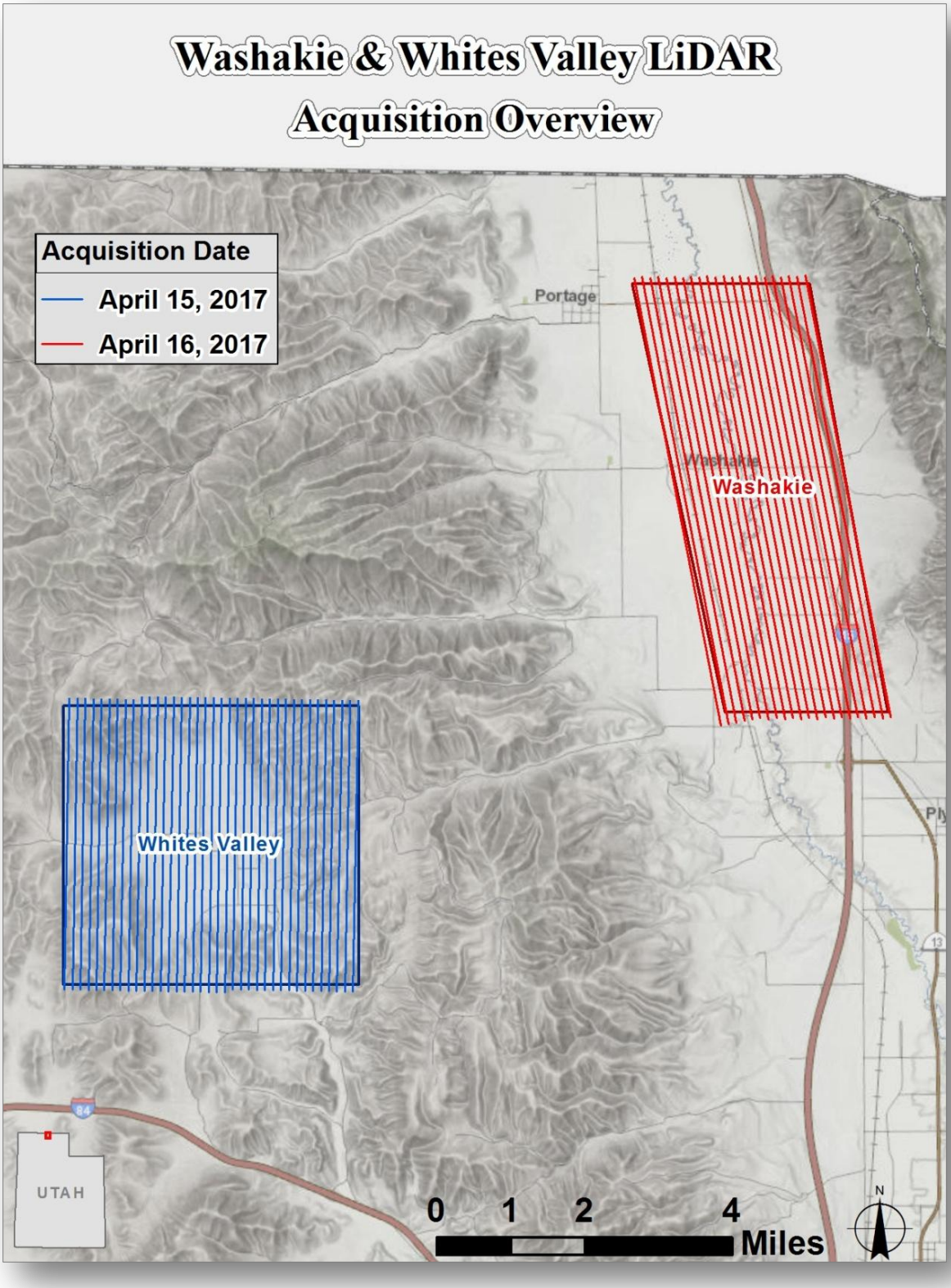


Exhibit 5: *Flight lines symbolized by acquisition date*



3. Ground Survey – Equipment and Methodology

Aero-Graphics surveyed 48 ground control points for use in data calibration as well as 146 QC check points in Vegetated and Non-Vegetated land cover classifications as an independent test of accuracy for this project. A combination of precise GPS surveying methods, including static and RTK observations were used to establish the 3D position of ground calibration points and QC check points. Calibration control point, QC check point, and base station coordinates can be found in Appendix A. LiDAR positional accuracy results can be found in section 5.

Exhibit 6: *Calibration Control Point number 102 (Washakie)*

Exhibit 7: *Calibration Control Point number 201 (Whites Valley)*

4. LiDAR Processing Workflow

a. **Absolute Sensor Calibration.** Our absolute sensor calibration adjusted for the difference in roll, pitch, heading, and scale between the raw laser point cloud from the sensor and surveyed control points on the ground.

b. **Kinematic Air Point Processing.** Differentially corrected the 1-second airborne GPS positions with ground base station; 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).

c. **Raw LiDAR Point Processing (Calibration).** Combined SBET with raw LiDAR range data; solved real-world position for each laser point; produced point cloud data by flight strip in ASPRS v1.4 .LAS format; output in NAD83 (2011) UTM Zone 12, meters.

d. **Relative Calibration.** Performed relative calibration by correcting for roll, pitch, heading, and scale discrepancies between adjacent flightlines; tested resulting relative accuracy. Results presented in Section 5.

e. **Vertical Accuracy Assessment.** Performed comparative tests that showed Z-differences between surveyed points and the laser point surface. Results presented in Section 5.

f. **Tiling & Long/Short Filtering.** Cut data into project-specified tiles and filtered out grossly long and short returns.

g. **Classified LAS Processing.** The point classification is performed as described below. The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

   All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro-flattened breaklines were then classified to Water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro-flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed. All bridge decks were classified to Class 17. All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data was classified using standard LAS overlap bit. These classes were created through automated processes only and were not verified for classification accuracy.

   All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. LP360 was used as a final check of the bare earth

dataset. LP360 was then used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. Aero-Graphics, Inc. proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

Exhibit 8: *USGS Version 1.2 minimum point cloud classification scheme used for this project*

CLASS #	CLASS NAME	DESCRIPTION
1	Processed, but unclassified	Points that do not fit any other classes
2	Bare earth	Bare earth surface
7	Low noise	Low points identified below surface
9	Water	Points inside of lakes/ponds
10	Ignored ground (near a breakline)	Points near breakline features; ignored in DEM creation process
17	Bridge decks	Points on bridge decks
18	High noise	High points identified above surface

h. **Hydro-Flattened Breakline Creation.** Class 2 (ground) LiDAR points were used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of inland streams and rivers with a 100-foot nominal width and inland ponds and lakes of 2 acres or greater surface area. Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Stream and River Islands, using LP360 functionality. Elevation values were assigned to all inland streams and rivers using Aero-Graphics, Inc. proprietary software. All Ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to Water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 1 meter was also used around each hydro-flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to ESRI shapefile format using ESRI conversion tools. Breaklines are reviewed against LiDAR intensity imagery to verify completeness of capture. All breaklines are then compared to TINs (triangular irregular networks) created from ground only points prior to water classification. The horizontal placement of breaklines is compared to terrain features and the breakline elevations are compared to LiDAR elevations to ensure all breaklines match the LiDAR within acceptable tolerances. Some deviation is expected between breakline and LiDAR elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once completeness, horizontal placement, and vertical variance is reviewed, all breaklines are reviewed for topological consistency and data integrity using a combination of ESRI ArcMap tools and proprietary tools.

i. **Hydro-Flattened Raster DEM Creation.** Class 2 (Ground) LiDAR points in conjunction with the hydro breaklines were used to create a 0.5 meter hydro-flattened raster DEM. Using LP360 along with automated scripting routines within ArcMap, an ERDAS Imagine .IMG file was created for each tile. Each surface is reviewed using ESRI ArcMap and ArcScene to check for any surface anomalies or incorrect elevations found within the surface.

j. **First Return Raster DSM Creation.** First return LiDAR points were used to create a 0.5 meter first-return raster DEM. Using LP360 along with automated scripting routines within ArcMap, an ERDAS Imagine .IMG file was created for each tile. Each surface is reviewed using ESRI ArcMap and ArcScene to check for any surface anomalies or incorrect elevations found within the surface.

k. **Intensity Image Creation.** TerraScan software was used to create the deliverable Intensity Images. All overlap classes were ignored during this process. This helps to ensure a more aesthetically pleasing image. The ESRI ArcMap software was then used to verify full project coverage. TIF/TFW files were then provided as the deliverable for this dataset requirement.

l. **Issues.** There were no issues to report for this project.

5. Accuracy Testing and Results

5.1 Relative Calibration Accuracy Results

Between-swath relative accuracy is defined as the elevation difference in overlapping areas between a given set of two adjacent flightlines. The statistics are based on the comparison of the flightlines and points listed below.

Washakie project area: (24 flightlines, > 382 million points)

- Between-swath relative accuracy **average** of 0.014 meters

Whites Valley project area: (39 flightlines, > 436 million points)

- Between-swath relative accuracy **average** of 0.020 meters

Within-swath relative accuracy is the amount of vertical separation, or "noise," among a set of points on open, paved ground that should have the same elevation. The within-swath relative accuracy average is less than **0.026 foot.**

5.2 Calibration Control Point Testing

Calibration Control Point reports were generated as a quality assurance check. Note that the results are not an independent assessment of the accuracy of the project deliverables, but rather an additional indication of the overall accuracy of the dataset. The location of each control point is displayed below. Detailed results are included in Appendix B.

Exhibit 9: *Calibration Control Point locations for the Washakie area*

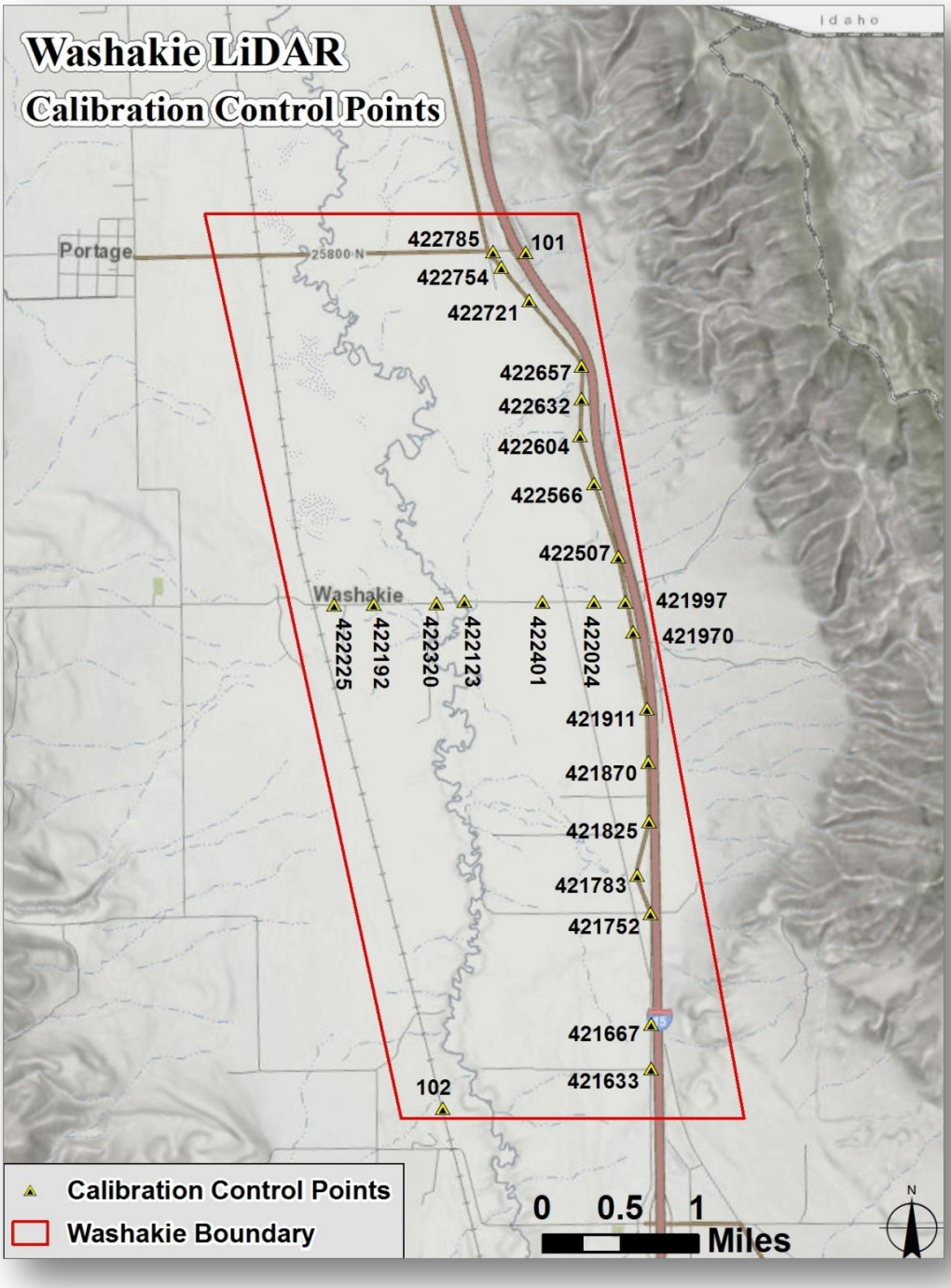
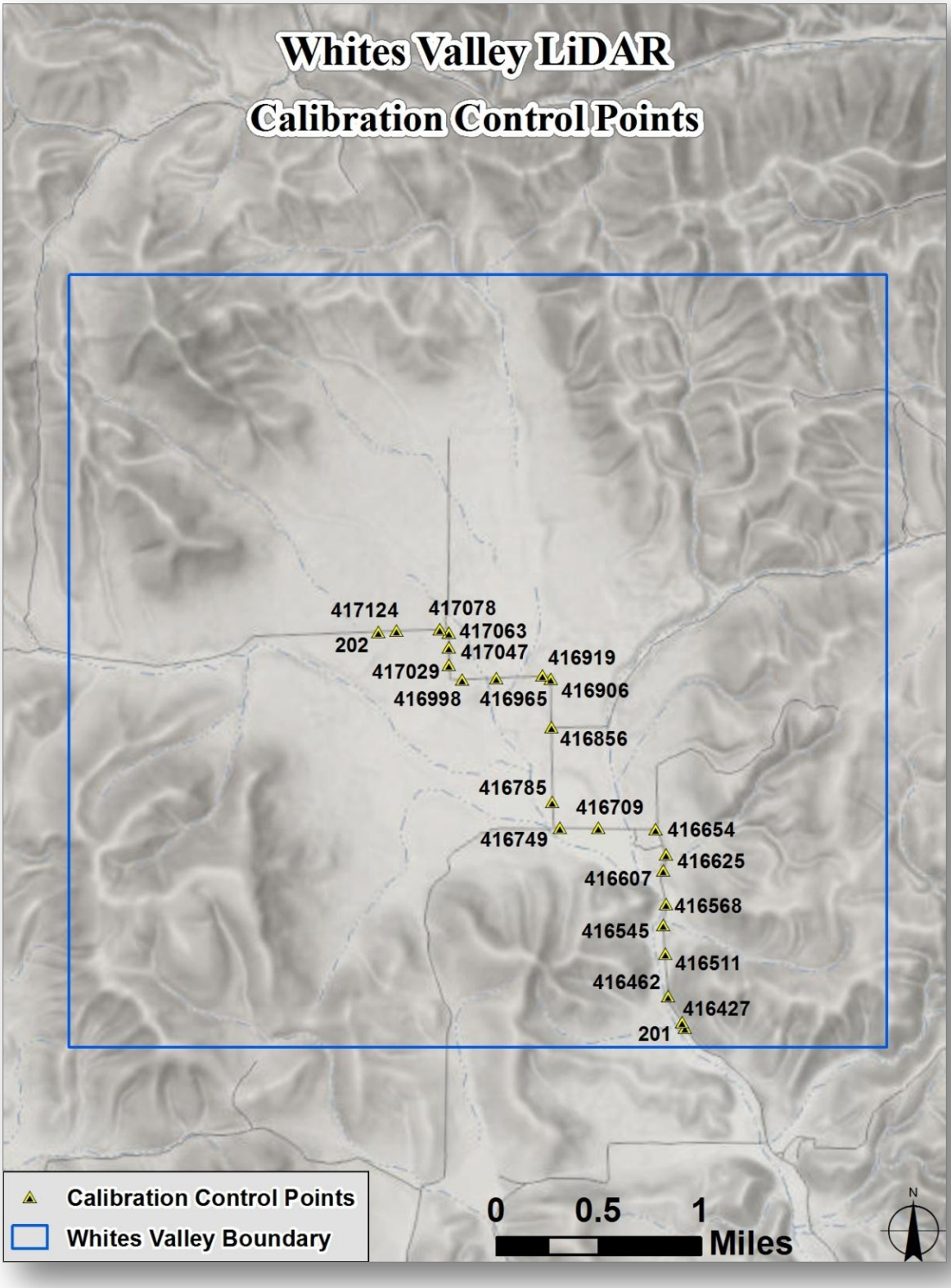


Exhibit 10: *Calibration Control Point locations for the Whites Valley area*



5.3 Point Cloud Testing

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw LiDAR point cloud swath files. NVA is defined as the elevation difference between the LiDAR surface and ground surveyed static points collected in open terrain (bare soil, sand, rocks, and short grass) as well as urban terrain (asphalt and concrete surfaces). The NVA for this project was tested with 39 check points in the Washakie area and 30 check points in the Whites Valley area. These check points were not used in the calibration or post processing of the LiDAR point cloud data. Elevations from the unclassified LiDAR surface were measured for the xy location of each check point. Elevations interpolated from the LiDAR surface were then compared to the elevation values of the surveyed control points.

Raw Non-vegetated Vertical Accuracy (Raw NVA): The tested Raw NVA for this dataset was found to be 0.020 meters in terms of the RMSEz. The resulting NVA stated as the 95% confidence level (RMSEz x 1.96) is 0.039 meters. Therefore this dataset meets the required NVA of 0.196 meters at the 95% confidence level as defined by the National Standards for Spatial Data Accuracy (NSSDA). Individual point results are included in Appendix B.

5.4 Digital Elevation Model (DEM) Testing

The project specifications require the accuracy of the derived DEM be calculated and reported in two ways: (1) Non-Vegetated Vertical Accuracy (NVA) calculated at a 95% confidence level in “bare earth” and “urban” land cover classes and (2) Vegetated Vertical Accuracy (VVA) in all vegetated land cover classes combined calculated based on the 95th percentile error. The NVA for this project was tested with 39 check points in the Washakie area and 30 check points in the Whites Valley area. The VVA was tested with 45 check points in the Washakie area and 32 check points in the Whites Valley area.

The tested Non-Vegetated Vertical Accuracy (NVA) for this dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.020 meters in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.039 meters. Therefore this dataset meets the required NVA of 0.196 meters at the 95% confidence level. Individual point results are included in Appendix B.

The tested Vegetated Vertical Accuracy (VVA) for this dataset captured from the DEM using bi-linear interpolation for all classes was found to be 0.066 meters. Therefore this dataset meets the required VVA of 0.294 meters based on the 95th percentile error. Individual point results are included in Appendix B.

Exhibit 11: *QC Check Point locations for the Washakie area*

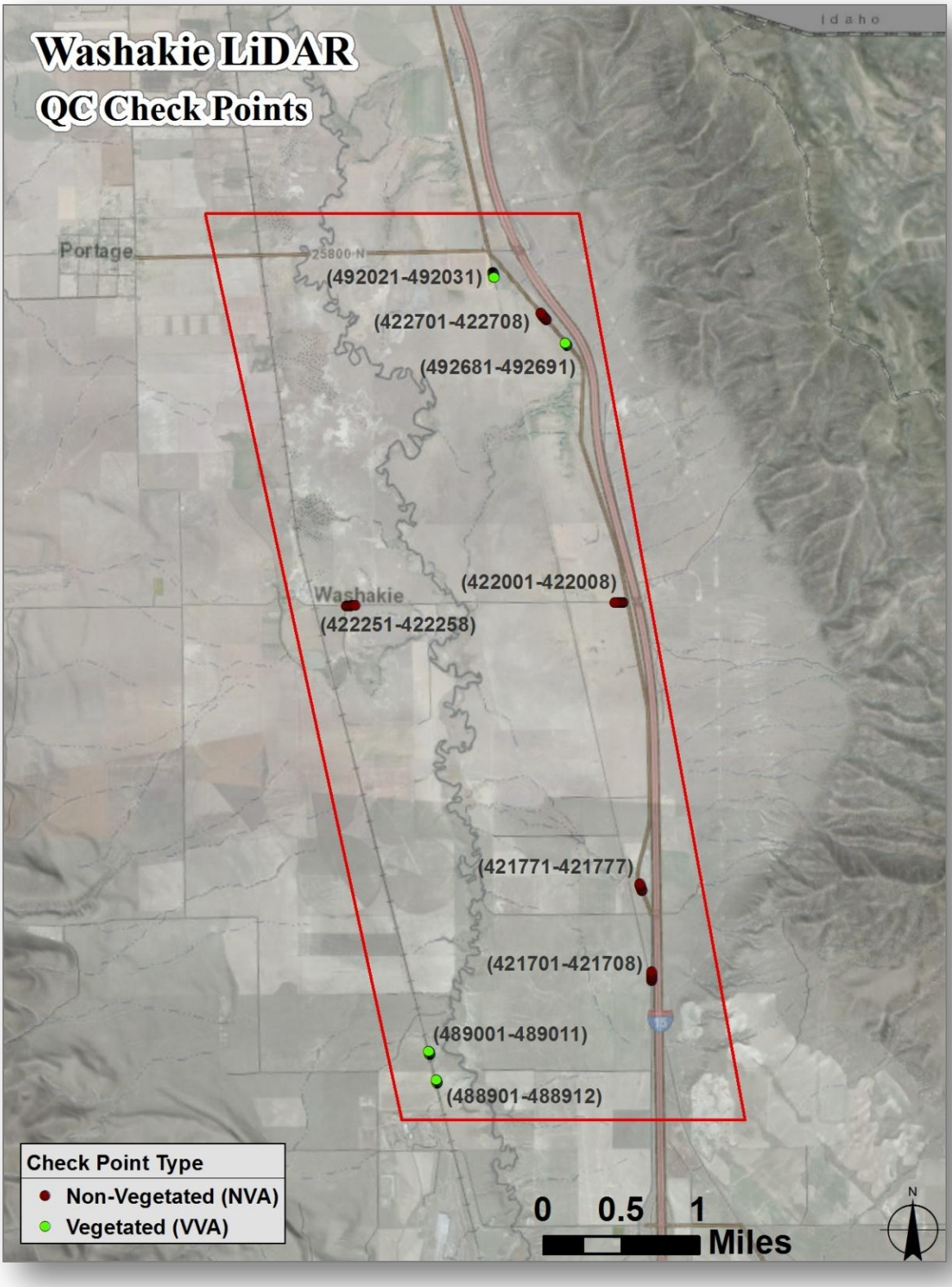
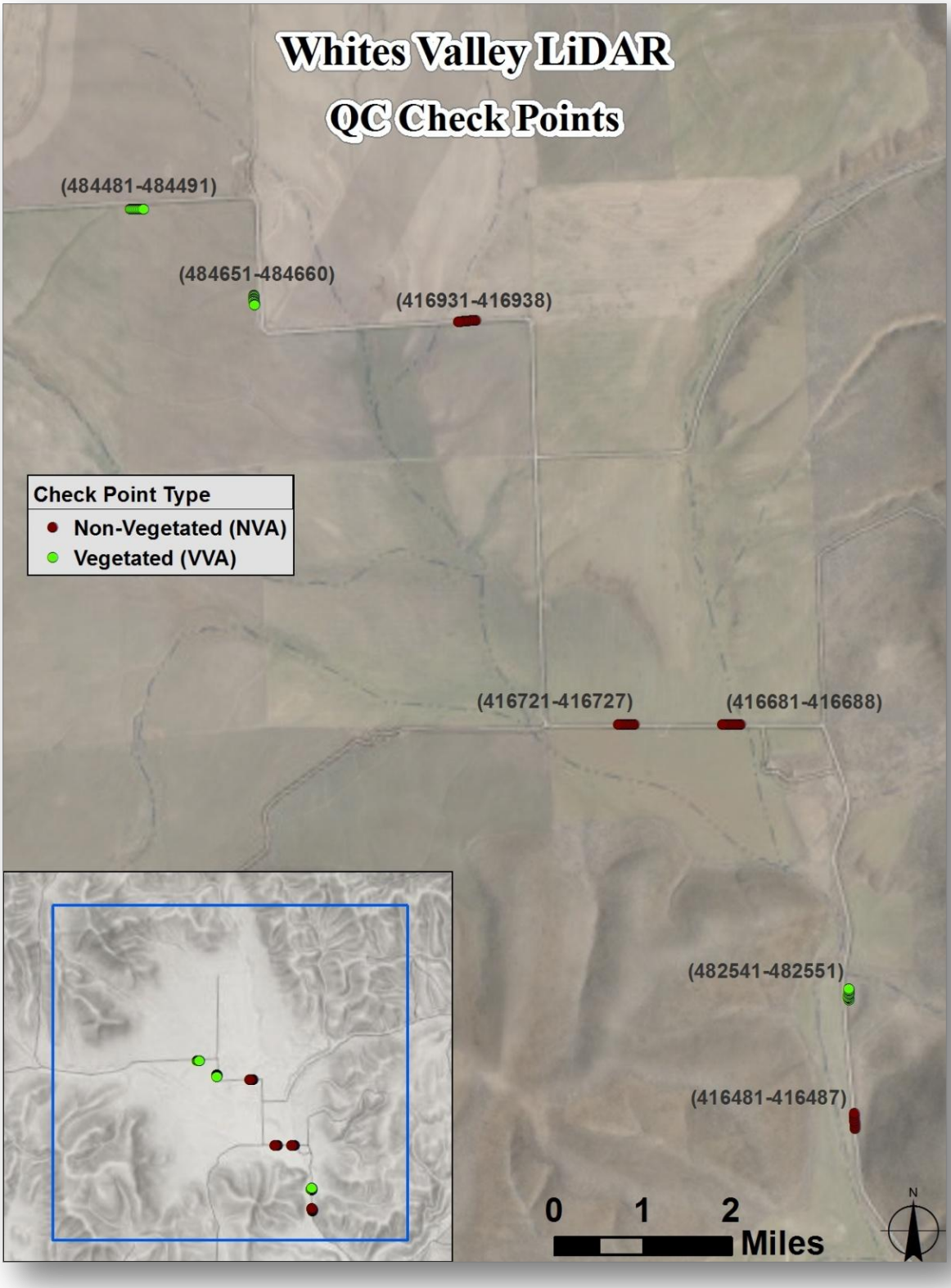


Exhibit 12: *QC Check Point locations for the Whites Valley area*



5.5 Data Density

The requirement for this project was to achieve a LiDAR point density of **8** points per square meter. The acquisition mission achieved an actual average of **13** points per square meter. The following two exhibits show the density of **all collected points.**

Exhibit 13: ***Washakie & Whites Valley – All returns*** *Laser Point Density by Frequency, points/m^2. Demonstrates the percentage of project tiles with points in a given density range*

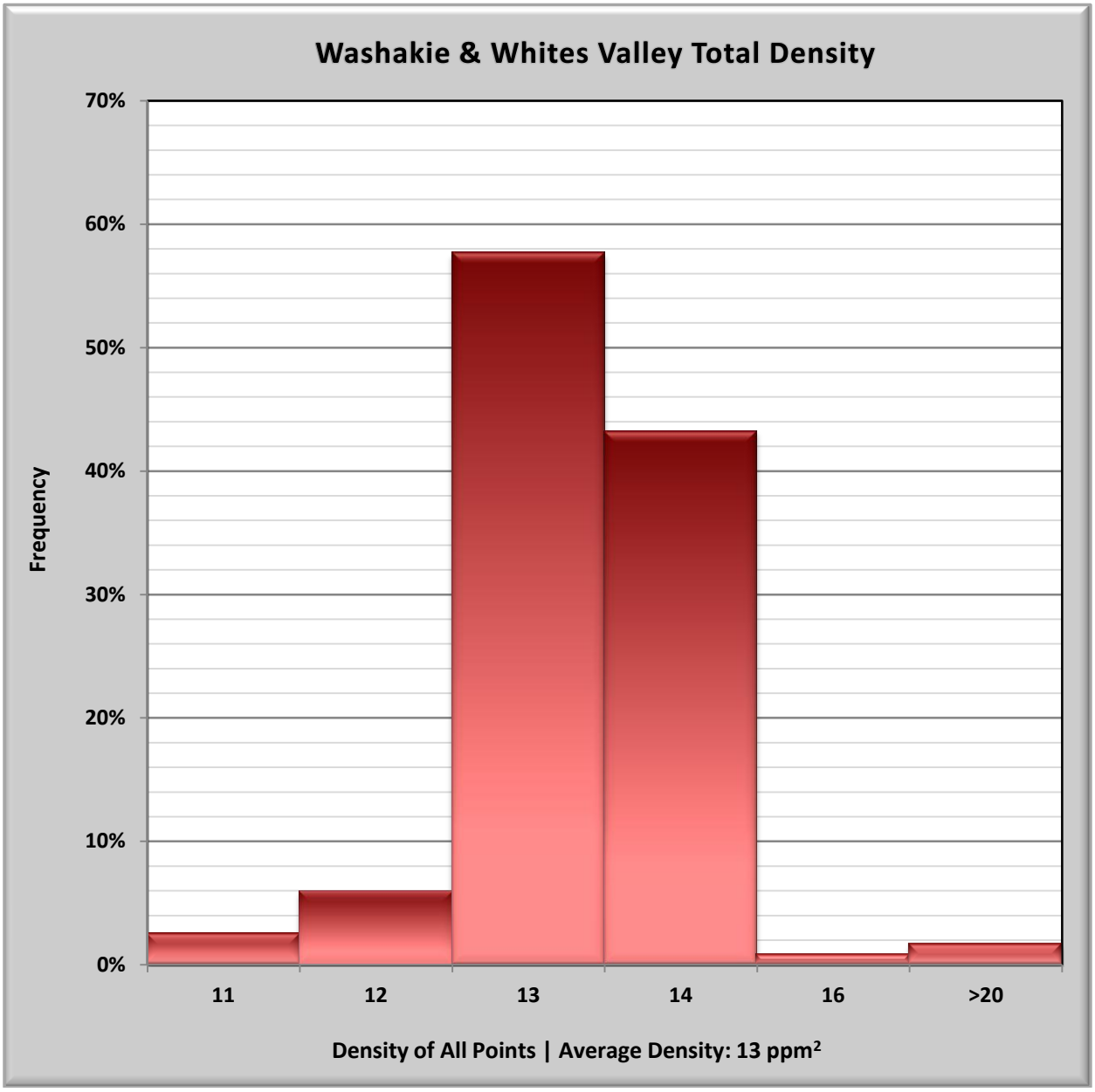
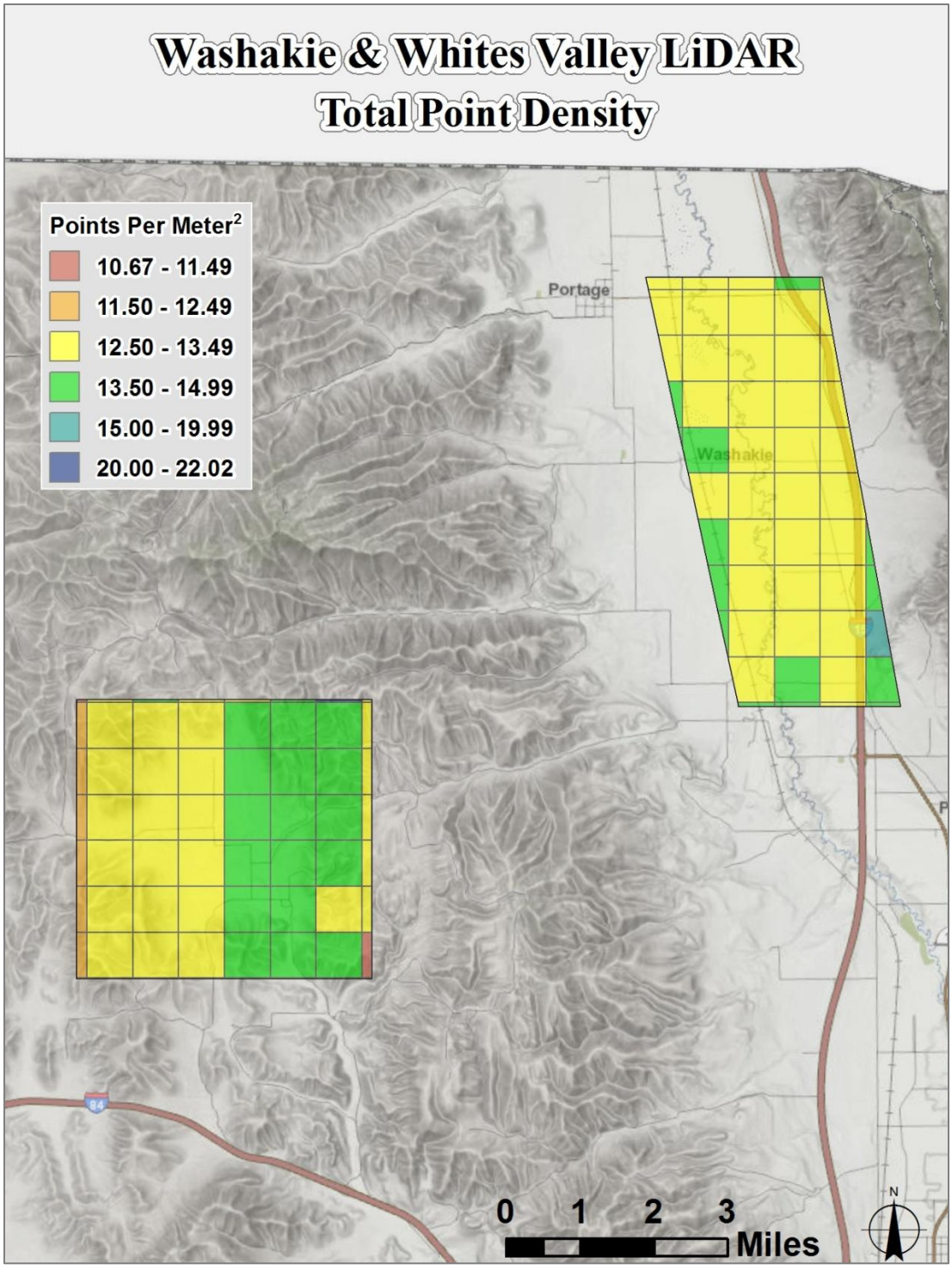


Exhibit 14: *Laser Point Density of All Returns by Tile, points/m^2*



The following two exhibits show the density of **ground classified points**. Factors such as vegetation, water, and buildings will reduce the density of points classified to the ground. For the Washakie & Whites Valley project, an average of **12** ground classified points per square meter was achieved.

Exhibit 15: ***Washakie & Whites Valley - Ground Classified*** *Laser Point Density by Frequency, points/m^2. Demonstrates the percentage of project tiles with points in a given density range*

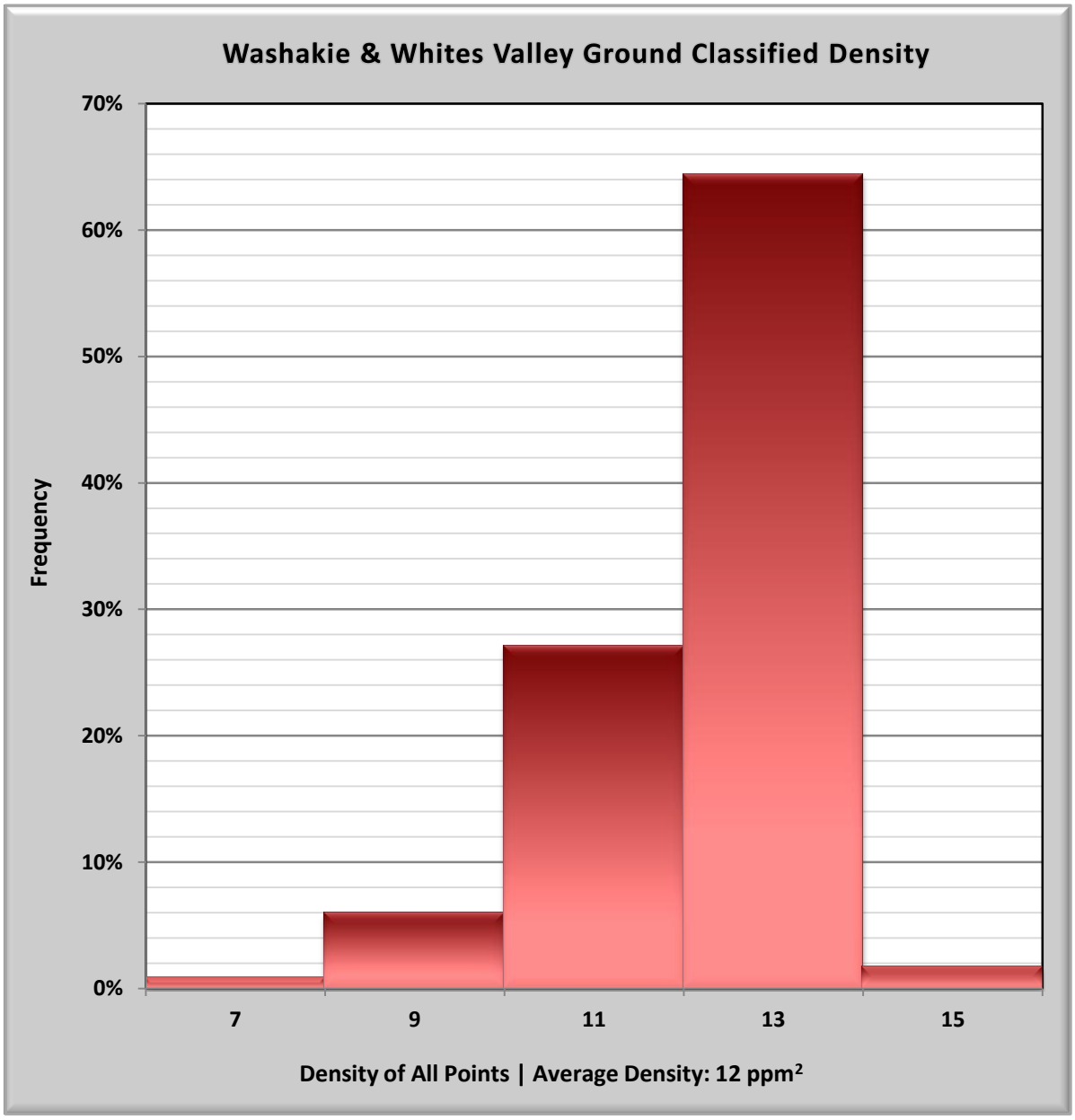
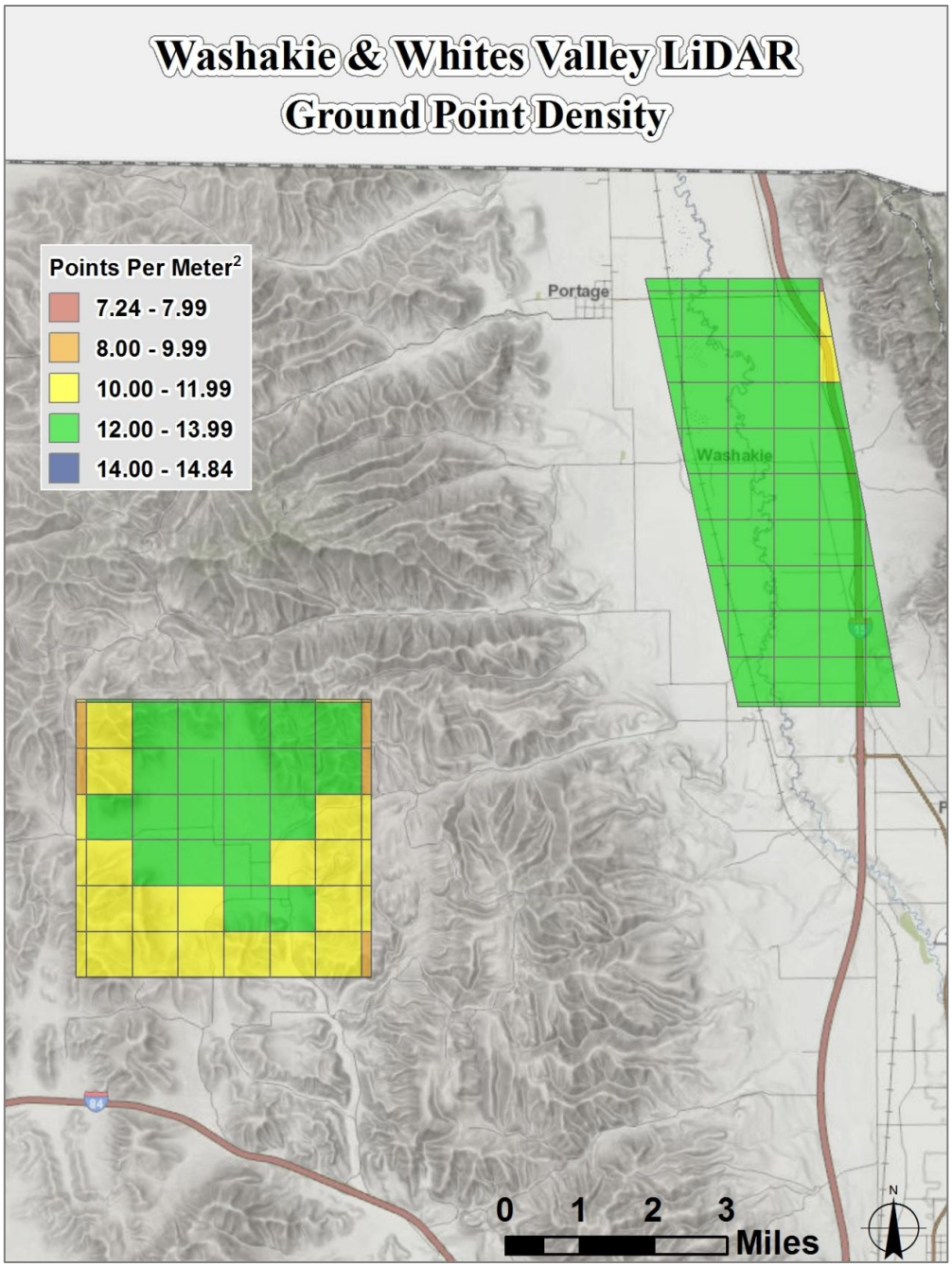


Exhibit 16: *Ground Classified Laser Point Density by Tile, points/m²*



5.6 Data Density Summary

Washakie & Whites Valley	Goal	Actual (mean)
Total Point Density:	8 points/m²	13 points/m²
Ground Classified Point Density:	-------	12 points/m²

6. Projection, Datums, and Mapping Units

Projection:		UTM Zone 12N
Datum	**Vertical:**	NAVD88 (GEOID12B)
	Horizontal:	NAD83 (2011)
Units:		Meters

7. Deliverables

LiDAR Point Data:	• Raw and classified LiDAR point cloud data in LAS v1.4 format
Raster Data:	• Bare-earth and first return DEMs with a cell size of 0.5 meters in ERDAS .IMG format • Intensity images at a 0.5 meter resolution in GeoTIFF format
Vector Data:	• Shapefiles containing processing boundary and tile index • Shapefiles containing all breaklines used for hydro-flattening • Separate shapefiles for control points and check points
Metadata:	• FGDC compliant metadata files in XML format
Report of Survey:	• Technical Project Report including methodology, accuracy, and results

*Tiling for the LiDAR deliverables is based on the U.S. National Grid System. Tile names are based on the SW corner of the tile. All .LAS tiles are 1,000 meters x 1,000 meters. All other deliverables are 2,000 meters x 2,000 meters.

Appendix A

Control Point Coordinates

Point	NAD83 (2011) UTM Zone 12		NAVD88 (GEOID12B)
	Easting	Northing	Elevation
101	401505.205	4647874.394	1362.609
102	400652.605	4639028.748	1342.089
201	390630.675	4633141.738	1534.734
202	388215.768	4636252.547	1591.538
416427	390610.347	4633182.513	1534.641
416462	390499.206	4633384.748	1537.600
416511	390475.739	4633725.682	1540.681
416545	390460.161	4633949.501	1545.919
416568	390480.947	4634112.005	1546.868
416607	390458.414	4634378.052	1560.584
416625	390481.321	4634502.015	1566.132
416654	390401.374	4634704.101	1563.835
416709	389948.640	4634712.356	1553.738
416749	389647.954	4634712.736	1553.685
416785	389588.386	4634916.212	1553.936
416856	389579.622	4635505.306	1565.246
416906	389574.358	4635884.231	1574.059
416919	389508.897	4635910.803	1572.804
416965	389148.021	4635892.673	1560.922
416998	388876.614	4635878.954	1565.479
417029	388772.298	4635997.109	1568.318
417047	388772.658	4636135.564	1570.074
417063	388772.224	4636251.565	1571.186
417078	388698.109	4636277.341	1573.828
417124	388358.594	4636265.288	1588.835
421633	402798.826	4639433.556	1372.409
421667	402798.853	4639896.774	1368.854
421752	402791.926	4641043.151	1349.395
421783	402658.490	4641439.754	1346.250
421825	402778.283	4641992.366	1343.847
421870	402771.439	4642601.300	1347.187
421911	402758.725	4643155.738	1354.649
421970	402611.989	4643949.043	1357.739
421997	402535.753	4644259.351	1355.133
422024	402207.963	4644260.117	1343.755
422123	400869.079	4644262.771	1330.893
422192	399933.871	4644233.162	1331.700

Point	Easting	Northing	Elevation
422225	399530.187	4644228.063	1332.590
422320	400587.094	4644240.505	1330.702
422401	401680.540	4644254.934	1336.376
422507	402463.254	4644722.899	1355.733
422566	402214.548	4645484.388	1353.477
422604	402070.294	4645980.433	1353.353
422632	402084.172	4646363.227	1351.953
422657	402081.038	4646698.580	1347.642
422721	401541.185	4647377.040	1343.450
422754	401250.511	4647718.711	1345.245
422785	401165.400	4647880.549	1347.184

QC Check Point Coordinates

Point	Type	Area	NAD83 (2011) UTM Zone 12		NAVD88 (GEOID12B)
			Easting	Northing	Elevation
416481	NVA	Whites Valley	390491.098	4633519.204	1538.030
416482	NVA	Whites Valley	390490.646	4633526.896	1538.094
416483	NVA	Whites Valley	390490.190	4633534.538	1538.175
416484	NVA	Whites Valley	390489.750	4633542.149	1538.256
416485	NVA	Whites Valley	390489.277	4633549.698	1538.342
416486	NVA	Whites Valley	390488.768	4633557.163	1538.417
416487	NVA	Whites Valley	390488.247	4633564.583	1538.487
416681	NVA	Whites Valley	390171.911	4634708.732	1554.553
416682	NVA	Whites Valley	390164.042	4634708.863	1554.516
416683	NVA	Whites Valley	390156.409	4634709.053	1554.475
416684	NVA	Whites Valley	390148.871	4634709.251	1554.444
416685	NVA	Whites Valley	390141.014	4634709.430	1554.425
416686	NVA	Whites Valley	390133.026	4634709.574	1554.417
416687	NVA	Whites Valley	390125.144	4634709.700	1554.401
416688	NVA	Whites Valley	390117.300	4634709.838	1554.398
416721	NVA	Whites Valley	389858.084	4634713.470	1553.668
416722	NVA	Whites Valley	389850.538	4634713.501	1553.673
416723	NVA	Whites Valley	389842.815	4634713.528	1553.680
416724	NVA	Whites Valley	389835.058	4634713.612	1553.677
416725	NVA	Whites Valley	389827.331	4634713.696	1553.668
416726	NVA	Whites Valley	389819.647	4634713.722	1553.666
416727	NVA	Whites Valley	389811.981	4634713.724	1553.665
416931	NVA	Whites Valley	389410.429	4635904.924	1569.365
416932	NVA	Whites Valley	389402.605	4635904.509	1568.843
416933	NVA	Whites Valley	389395.027	4635904.140	1568.294
416934	NVA	Whites Valley	389387.643	4635903.738	1567.708

Point	Type	Area	Easting	Northing	Elevation
416935	NVA	Whites Valley	389380.422	4635903.271	1567.124
416936	NVA	Whites Valley	389373.119	4635902.845	1566.470
416937	NVA	Whites Valley	389365.688	4635902.385	1565.796
416938	NVA	Whites Valley	389358.238	4635901.936	1565.112
421701	NVA	Washakie	402800.374	4640355.870	1361.405
421702	NVA	Washakie	402800.229	4640369.391	1361.167
421703	NVA	Washakie	402800.151	4640382.939	1360.960
421704	NVA	Washakie	402800.040	4640396.485	1360.755
421705	NVA	Washakie	402799.969	4640410.036	1360.594
421706	NVA	Washakie	402799.931	4640423.565	1360.452
421707	NVA	Washakie	402799.867	4640437.085	1360.275
421708	NVA	Washakie	402799.770	4640450.595	1360.158
421771	NVA	Washakie	402703.555	4641283.673	1347.208
421772	NVA	Washakie	402698.724	4641296.320	1347.144
421773	NVA	Washakie	402693.905	4641308.952	1347.095
421774	NVA	Washakie	402689.119	4641321.567	1347.087
421775	NVA	Washakie	402684.417	4641334.165	1347.107
421776	NVA	Washakie	402679.878	4641346.825	1347.049
421777	NVA	Washakie	402675.550	4641359.629	1346.980
422001	NVA	Washakie	402504.563	4644260.368	1354.081
422002	NVA	Washakie	402495.830	4644260.284	1353.750
422003	NVA	Washakie	402485.903	4644260.232	1353.338
422004	NVA	Washakie	402474.736	4644260.254	1352.908
422005	NVA	Washakie	402462.496	4644260.314	1352.428
422006	NVA	Washakie	402449.421	4644260.363	1351.908
422007	NVA	Washakie	402435.925	4644260.416	1351.334
422008	NVA	Washakie	402422.232	4644260.450	1350.783
422251	NVA	Washakie	399650.268	4644225.377	1332.310
422252	NVA	Washakie	399663.738	4644225.469	1332.281
422253	NVA	Washakie	399677.216	4644225.636	1332.245
422254	NVA	Washakie	399690.702	4644225.853	1332.226
422255	NVA	Washakie	399704.198	4644226.046	1332.208
422256	NVA	Washakie	399717.722	4644226.245	1332.178
422257	NVA	Washakie	399731.277	4644226.444	1332.144
422258	NVA	Washakie	399744.850	4644226.558	1332.098
422701	NVA	Washakie	401715.876	4647169.773	1347.020
422702	NVA	Washakie	401707.107	4647180.257	1346.936
422703	NVA	Washakie	401698.331	4647190.781	1346.816
422704	NVA	Washakie	401689.526	4647201.353	1346.642
422705	NVA	Washakie	401680.692	4647212.011	1346.395
422706	NVA	Washakie	401671.836	4647222.737	1346.061
422707	NVA	Washakie	401662.968	4647233.506	1345.667
422708	NVA	Washakie	401654.110	4647244.250	1345.250

Point	Type	Area	Easting	Northing	Elevation
482541	VVA	Whites Valley	390477.735	4633896.435	1544.638
482542	VVA	Whites Valley	390477.244	4633899.373	1544.836
482543	VVA	Whites Valley	390476.844	4633902.291	1544.991
482544	VVA	Whites Valley	390476.779	4633905.318	1545.147
482545	VVA	Whites Valley	390477.011	4633908.437	1545.290
482546	VVA	Whites Valley	390477.446	4633911.707	1545.421
482547	VVA	Whites Valley	390477.854	4633915.182	1545.566
482548	VVA	Whites Valley	390478.258	4633918.658	1545.727
482549	VVA	Whites Valley	390478.553	4633922.082	1545.855
482550	VVA	Whites Valley	390478.662	4633925.474	1545.964
482551	VVA	Whites Valley	390478.644	4633928.752	1546.055
484481	VVA	Whites Valley	388397.079	4636245.557	1586.776
484482	VVA	Whites Valley	388400.559	4636245.550	1586.617
484483	VVA	Whites Valley	388404.124	4636245.541	1586.432
484484	VVA	Whites Valley	388407.802	4636245.494	1586.225
484485	VVA	Whites Valley	388411.615	4636245.454	1586.027
484486	VVA	Whites Valley	388415.542	4636245.412	1585.810
484487	VVA	Whites Valley	388419.526	4636245.351	1585.599
484488	VVA	Whites Valley	388423.540	4636245.356	1585.396
484489	VVA	Whites Valley	388427.600	4636245.338	1585.167
484490	VVA	Whites Valley	388431.729	4636245.363	1584.920
484491	VVA	Whites Valley	388435.943	4636245.454	1584.667
484651	VVA	Whites Valley	388756.699	4635989.658	1568.962
484652	VVA	Whites Valley	388756.917	4635986.380	1569.152
484653	VVA	Whites Valley	388757.193	4635982.958	1569.292
484654	VVA	Whites Valley	388757.492	4635979.579	1569.366
484655	VVA	Whites Valley	388757.822	4635976.300	1569.400
484656	VVA	Whites Valley	388758.088	4635973.010	1569.430
484657	VVA	Whites Valley	388758.324	4635969.664	1569.435
484658	VVA	Whites Valley	388758.545	4635966.215	1569.406
484659	VVA	Whites Valley	388758.734	4635962.684	1569.366
484660	VVA	Whites Valley	388758.927	4635959.111	1569.317
488901	VVA	Washakie	400585.696	4639300.560	1339.183
488902	VVA	Washakie	400584.823	4639303.659	1339.155
488903	VVA	Washakie	400583.960	4639306.816	1339.085
488904	VVA	Washakie	400583.109	4639310.011	1339.014
488905	VVA	Washakie	400582.273	4639313.200	1338.974
488906	VVA	Washakie	400581.488	4639316.186	1338.926
488907	VVA	Washakie	400580.726	4639319.014	1338.850
488908	VVA	Washakie	400579.929	4639321.749	1338.812
488909	VVA	Washakie	400579.110	4639324.527	1338.777
488910	VVA	Washakie	400578.426	4639327.286	1338.686
488911	VVA	Washakie	400577.732	4639330.206	1338.613

Point	Type	Area	Easting	Northing	Elevation
488912	VVA	Washakie	400576.988	4639333.151	1338.538
489001	VVA	Washakie	400509.263	4639595.455	1336.369
489002	VVA	Washakie	400508.621	4639597.970	1336.380
489003	VVA	Washakie	400507.815	4639600.908	1336.314
489004	VVA	Washakie	400506.907	4639604.223	1336.280
489005	VVA	Washakie	400505.941	4639607.839	1336.264
489006	VVA	Washakie	400504.997	4639611.645	1336.244
489007	VVA	Washakie	400504.126	4639615.499	1336.242
489008	VVA	Washakie	400503.238	4639619.262	1336.239
489009	VVA	Washakie	400502.311	4639622.946	1336.239
489010	VVA	Washakie	400501.375	4639626.588	1336.248
489011	VVA	Washakie	400500.476	4639630.126	1336.239
492021	VVA	Washakie	401159.542	4647665.328	1341.252
492022	VVA	Washakie	401160.572	4647660.621	1341.116
492023	VVA	Washakie	401161.678	4647655.648	1341.014
492024	VVA	Washakie	401162.808	4647650.359	1340.906
492025	VVA	Washakie	401164.091	4647644.803	1340.793
492026	VVA	Washakie	401165.442	4647639.085	1340.668
492027	VVA	Washakie	401166.815	4647633.200	1340.515
492028	VVA	Washakie	401168.184	4647627.251	1340.364
492029	VVA	Washakie	401169.548	4647621.328	1340.232
492030	VVA	Washakie	401170.908	4647615.435	1340.098
492031	VVA	Washakie	401172.215	4647609.546	1339.965
492681	VVA	Washakie	401926.152	4646909.490	1347.609
492682	VVA	Washakie	401924.072	4646911.886	1347.592
492683	VVA	Washakie	401922.029	4646914.280	1347.561
492684	VVA	Washakie	401919.950	4646916.688	1347.549
492685	VVA	Washakie	401917.883	4646919.146	1347.515
492686	VVA	Washakie	401915.826	4646921.650	1347.478
492687	VVA	Washakie	401913.758	4646924.094	1347.478
492688	VVA	Washakie	401911.744	4646926.372	1347.499
492689	VVA	Washakie	401909.785	4646928.605	1347.507
492690	VVA	Washakie	401907.831	4646930.859	1347.500
492691	VVA	Washakie	401905.826	4646933.170	1347.488

Base Station Coordinates

Base Station	WGS84		
	Latitude	Longitude	Height
UTRS	41° 47' 15.86153"	-112° 09' 53.51884"	1334.809

NGS Reference Station Coordinates

NGS Tristation/BM	NAD83 (2011)		NAVD88 (Geoid12B/OPUS Solution)
	Latitude	Longitude	Elevation (usft)
Plymouth 1963	41° 53' 42.86814"	-112° 10' 04.12609"	4604.979

Appendix B

Calibrated Control Point Report

Point	Easting	Northing	Known Z	Laser Z	Dz
101	401505.205	4647874.394	1362.609	1362.63	0.021
102	400652.605	4639028.748	1342.089	1342.12	0.031
201	390630.675	4633141.738	1534.734	1534.75	0.016
202	388215.768	4636252.547	1591.538	1591.54	0.002
421633	402798.826	4639433.556	1372.409	1372.43	0.021
421667	402798.853	4639896.774	1368.854	1368.88	0.026
421752	402791.926	4641043.151	1349.395	1349.43	0.035
421783	402658.49	4641439.754	1346.250	1346.29	0.04
421825	402778.283	4641992.366	1343.847	1343.88	0.033
421870	402771.439	4642601.300	1347.187	1347.21	0.023
421911	402758.725	4643155.738	1354.649	1354.69	0.041
421970	402611.989	4643949.043	1357.739	1357.78	0.041
421997	402535.753	4644259.351	1355.133	1355.15	0.017
422024	402207.963	4644260.117	1343.755	1343.76	0.005
422123	400869.079	4644262.771	1330.893	1330.90	0.007
422192	399933.871	4644233.162	1331.700	1331.70	0
422225	399530.187	4644228.063	1332.590	1332.60	0.01
422320	400587.094	4644240.505	1330.702	1330.68	-0.022
422401	401680.54	4644254.934	1336.376	1336.36	-0.016
422507	402463.254	4644722.899	1355.733	1355.76	0.027
422566	402214.548	4645484.388	1353.477	1353.42	-0.057
422604	402070.294	4645980.433	1353.353	1353.31	-0.043
422632	402084.172	4646363.227	1351.953	1351.89	-0.063
422657	402081.038	4646698.580	1347.642	1347.58	-0.062
422721	401541.185	4647377.040	1343.450	1343.46	0.01
422754	401250.511	4647718.711	1345.245	1345.23	-0.015
422785	401165.4	4647880.549	1347.184	1347.18	-0.004
416427	390610.347	4633182.513	1534.641	1534.65	0.009
416462	390499.206	4633384.748	1537.600	1537.60	0
416511	390475.739	4633725.682	1540.681	1540.70	0.019
416545	390460.161	4633949.501	1545.919	1545.93	0.011

Point	Easting	Northing	Known Z	Laser Z	Dz
416568	390480.947	4634112.005	1546.868	1546.84	-0.028
416607	390458.414	4634378.052	1560.584	1560.54	-0.044
416625	390481.321	4634502.015	1566.132	1566.11	-0.022
416654	390401.374	4634704.101	1563.835	1563.83	-0.005
416709	389948.64	4634712.356	1553.738	1553.73	-0.008
416749	389647.954	4634712.736	1553.685	1553.69	0.005
416785	389588.386	4634916.212	1553.936	1553.96	0.024
416856	389579.622	4635505.306	1565.246	1565.26	0.014
416906	389574.358	4635884.231	1574.059	1574.07	0.011
416919	389508.897	4635910.803	1572.804	1572.82	0.016
416965	389148.021	4635892.673	1560.922	1560.93	0.008
416998	388876.614	4635878.954	1565.479	1565.49	0.011
417029	388772.298	4635997.109	1568.318	1568.30	-0.018
417047	388772.658	4636135.564	1570.074	1570.08	0.006
417063	388772.224	4636251.565	1571.186	1571.20	0.014
417078	388698.109	4636277.341	1573.828	1573.86	0.032
417124	388358.594	4636265.288	1588.835	1588.84	0.005
	Average Dz	0.004			
	Minimum Dz	-0.063			
	Maximum Dz	0.041			
	Root Mean Square	0.026			
	Std. Deviation	0.026			

Raw NVA Check Point Report

Point	Easting	Northing	Known Z	Laser Z	Dz
421701	402800.374	4640355.87	1361.405	1361.42	0.015
421702	402800.229	4640369.391	1361.167	1361.19	0.023
421703	402800.151	4640382.939	1360.96	1360.98	0.02
421704	402800.04	4640396.485	1360.755	1360.78	0.025
421705	402799.969	4640410.036	1360.594	1360.61	0.016
421706	402799.931	4640423.565	1360.452	1360.48	0.028
421707	402799.867	4640437.085	1360.275	1360.31	0.035
421708	402799.77	4640450.595	1360.158	1360.19	0.032
421771	402703.555	4641283.673	1347.208	1347.24	0.032
421772	402698.724	4641296.32	1347.144	1347.17	0.026
421773	402693.905	4641308.952	1347.095	1347.12	0.025
421774	402689.119	4641321.567	1347.087	1347.12	0.033
421775	402684.417	4641334.165	1347.107	1347.13	0.023
421776	402679.878	4641346.825	1347.049	1347.07	0.021
421777	402675.55	4641359.629	1346.98	1347.01	0.03
422001	402504.563	4644260.368	1354.081	1354.11	0.029
422002	402495.83	4644260.284	1353.75	1353.78	0.03
422003	402485.903	4644260.232	1353.338	1353.37	0.032
422004	402474.736	4644260.254	1352.908	1352.92	0.012
422005	402462.496	4644260.314	1352.428	1352.46	0.032
422006	402449.421	4644260.363	1351.908	1351.93	0.022
422007	402435.925	4644260.416	1351.334	1351.34	0.006
422008	402422.232	4644260.450	1350.783	1350.79	0.007
422251	399650.268	4644225.377	1332.31	1332.28	-0.03
422252	399663.738	4644225.469	1332.281	1332.24	-0.041
422253	399677.216	4644225.636	1332.245	1332.22	-0.025
422254	399690.702	4644225.853	1332.226	1332.21	-0.016
422255	399704.198	4644226.046	1332.208	1332.19	-0.018
422256	399717.722	4644226.245	1332.178	1332.16	-0.018
422257	399731.277	4644226.444	1332.144	1332.11	-0.034
422258	399744.850	4644226.558	1332.098	1332.08	-0.018
422701	401715.876	4647169.773	1347.020	1347.04	0.02
422702	401707.107	4647180.257	1346.936	1346.97	0.034
422703	401698.331	4647190.781	1346.816	1346.84	0.024
422704	401689.526	4647201.353	1346.642	1346.66	0.018
422705	401680.692	4647212.011	1346.395	1346.41	0.015
422706	401671.836	4647222.737	1346.061	1346.07	0.009
422707	401662.968	4647233.506	1345.667	1345.67	0.003
422708	401654.110	4647244.250	1345.250	1345.26	0.01
416481	390491.098	4633519.204	1538.030	1538.05	0.02
416482	390490.646	4633526.896	1538.094	1538.12	0.026
416483	390490.190	4633534.538	1538.175	1538.19	0.015

Point	Easting	Northing	Known Z	Laser Z	Dz
416484	390489.750	4633542.149	1538.256	1538.28	0.024
416485	390489.277	4633549.698	1538.342	1538.35	0.008
416486	390488.768	4633557.163	1538.417	1538.41	-0.007
416487	390488.247	4633564.583	1538.487	1538.49	0.003
416681	390171.911	4634708.732	1554.553	1554.58	0.027
416682	390164.042	4634708.863	1554.516	1554.53	0.014
416683	390156.409	4634709.053	1554.475	1554.47	-0.005
416684	390148.871	4634709.251	1554.444	1554.45	0.006
416685	390141.014	4634709.430	1554.425	1554.43	0.005
416686	390133.026	4634709.574	1554.417	1554.42	0.003
416687	390125.144	4634709.700	1554.401	1554.41	0.009
416688	390117.300	4634709.838	1554.398	1554.4	0.002
416721	389858.084	4634713.470	1553.668	1553.67	0.002
416722	389850.538	4634713.501	1553.673	1553.67	-0.003
416723	389842.815	4634713.528	1553.68	1553.67	-0.01
416724	389835.058	4634713.612	1553.677	1553.67	-0.007
416725	389827.331	4634713.696	1553.668	1553.65	-0.018
416726	389819.647	4634713.722	1553.666	1553.66	-0.006
416727	389811.981	4634713.724	1553.665	1553.67	0.005
416931	389410.429	4635904.924	1569.365	1569.37	0.005
416932	389402.605	4635904.509	1568.843	1568.85	0.007
416933	389395.027	4635904.140	1568.294	1568.29	-0.004
416934	389387.643	4635903.738	1567.708	1567.70	-0.008
416935	389380.422	4635903.271	1567.124	1567.11	-0.014
416936	389373.119	4635902.845	1566.470	1566.45	-0.02
416937	389365.688	4635902.385	1565.796	1565.78	-0.016
	Average Dz	0.008			
	Minimum Dz	-0.041			
	Maximum Dz	0.035			
	Root Mean Square	0.020			
	Std. Deviation	0.019			
	95% Confidence Level	0.039			

DEM - NVA Check Point Report

Point	Easting	Northing	Known Z	Laser Z	Dz
416481	390491.098	4633519.204	1538.03	1538.04	0.01
416482	390490.646	4633526.896	1538.094	1538.11	0.016
416483	390490.19	4633534.538	1538.175	1538.19	0.015
416484	390489.75	4633542.149	1538.256	1538.27	0.014
416485	390489.277	4633549.698	1538.342	1538.36	0.018
416486	390488.768	4633557.163	1538.417	1538.42	0.003
416487	390488.247	4633564.583	1538.487	1538.48	-0.007
416681	390171.911	4634708.732	1554.553	1554.58	0.027
416682	390164.042	4634708.863	1554.516	1554.53	0.014
416683	390156.409	4634709.053	1554.475	1554.48	0.005
416684	390148.871	4634709.251	1554.444	1554.45	0.006
416685	390141.014	4634709.43	1554.425	1554.44	0.015
416686	390133.026	4634709.574	1554.417	1554.41	-0.007
416687	390125.144	4634709.7	1554.401	1554.41	0.009
416688	390117.3	4634709.838	1554.398	1554.4	0.002
416721	389858.084	4634713.47	1553.668	1553.66	-0.008
416722	389850.538	4634713.501	1553.673	1553.66	-0.013
416723	389842.815	4634713.528	1553.68	1553.67	-0.01
416724	389835.058	4634713.612	1553.677	1553.67	-0.007
416725	389827.331	4634713.696	1553.668	1553.65	-0.018
416726	389819.647	4634713.722	1553.666	1553.66	-0.006
416727	389811.981	4634713.724	1553.665	1553.67	0.005
416931	389410.429	4635904.924	1569.365	1569.36	-0.005
416932	389402.605	4635904.509	1568.843	1568.84	-0.003
416933	389395.027	4635904.14	1568.294	1568.29	-0.004
416934	389387.643	4635903.738	1567.708	1567.7	-0.008
416935	389380.422	4635903.271	1567.124	1567.12	-0.004
416936	389373.119	4635902.845	1566.47	1566.46	-0.01
416937	389365.688	4635902.385	1565.796	1565.78	-0.016
416938	389358.238	4635901.936	1565.112	1565.11	-0.002
421701	402800.374	4640355.87	1361.405	1361.43	0.025
421702	402800.229	4640369.391	1361.167	1361.19	0.023
421703	402800.151	4640382.939	1360.96	1360.98	0.02
421704	402800.04	4640396.485	1360.755	1360.78	0.025
421705	402799.969	4640410.036	1360.594	1360.61	0.016
421706	402799.931	4640423.565	1360.452	1360.48	0.028
421707	402799.867	4640437.085	1360.275	1360.31	0.035
421708	402799.77	4640450.595	1360.158	1360.19	0.032
421771	402703.555	4641283.673	1347.208	1347.24	0.032
421772	402698.724	4641296.32	1347.144	1347.18	0.036
421773	402693.905	4641308.952	1347.095	1347.12	0.025
421774	402689.119	4641321.567	1347.087	1347.12	0.033

Point	Easting	Northing	Known Z	Laser Z	Dz
421775	402684.417	4641334.165	1347.107	1347.13	0.023
421776	402679.878	4641346.825	1347.049	1347.08	0.031
421777	402675.55	4641359.629	1346.98	1347	0.02
422001	402504.563	4644260.368	1354.081	1354.12	0.039
422002	402495.83	4644260.284	1353.75	1353.79	0.04
422003	402485.903	4644260.232	1353.338	1353.37	0.032
422004	402474.736	4644260.254	1352.908	1352.92	0.012
422005	402462.496	4644260.314	1352.428	1352.45	0.022
422006	402449.421	4644260.363	1351.908	1351.92	0.012
422007	402435.925	4644260.416	1351.334	1351.34	0.006
422008	402422.232	4644260.45	1350.783	1350.79	0.007
422251	399650.268	4644225.377	1332.31	1332.28	-0.03
422252	399663.738	4644225.469	1332.281	1332.26	-0.021
422253	399677.216	4644225.636	1332.245	1332.22	-0.025
422254	399690.702	4644225.853	1332.226	1332.2	-0.026
422255	399704.198	4644226.046	1332.208	1332.18	-0.028
422256	399717.722	4644226.245	1332.178	1332.16	-0.018
422257	399731.277	4644226.444	1332.144	1332.11	-0.034
422258	399744.85	4644226.558	1332.098	1332.08	-0.018
422701	401715.876	4647169.773	1347.02	1347.04	0.02
422702	401707.107	4647180.257	1346.936	1346.97	0.034
422703	401698.331	4647190.781	1346.816	1346.84	0.024
422704	401689.526	4647201.353	1346.642	1346.66	0.018
422705	401680.692	4647212.011	1346.395	1346.41	0.015
422706	401671.836	4647222.737	1346.061	1346.07	0.009
422707	401662.968	4647233.506	1345.667	1345.67	0.003
422708	401654.11	4647244.25	1345.25	1345.26	0.01
	Average Dz	0.008			
	Minimum Dz	-0.034			
	Maximum Dz	0.040			
	Root Mean Square	0.021			
	Std. Deviation	0.019			
	95% Confidence Level	0.039			

DEM - VVA Check Point Report

Point	Easting	Northing	Known Z	Laser Z	Dz
482541	390477.735	4633896.435	1544.638	1544.67	0.032
482542	390477.244	4633899.373	1544.836	1544.84	0.004
482543	390476.844	4633902.291	1544.991	1544.99	-0.001
482544	390476.779	4633905.318	1545.147	1545.15	0.003
482545	390477.011	4633908.437	1545.29	1545.32	0.03
482546	390477.446	4633911.707	1545.421	1545.44	0.019
482547	390477.854	4633915.182	1545.566	1545.58	0.014
482548	390478.258	4633918.658	1545.727	1545.76	0.033
482549	390478.553	4633922.082	1545.855	1545.88	0.025
482550	390478.662	4633925.474	1545.964	1545.98	0.016
482551	390478.644	4633928.752	1546.055	1546.03	-0.025
484481	388397.079	4636245.557	1586.776	1586.81	0.034
484482	388400.559	4636245.55	1586.617	1586.65	0.033
484483	388404.124	4636245.541	1586.432	1586.46	0.028
484484	388407.802	4636245.494	1586.225	1586.24	0.015
484485	388411.615	4636245.454	1586.027	1586.06	0.033
484486	388415.542	4636245.412	1585.81	1585.85	0.04
484487	388419.526	4636245.351	1585.599	1585.63	0.031
484488	388423.54	4636245.356	1585.396	1585.43	0.034
484489	388427.6	4636245.338	1585.167	1585.21	0.043
484490	388431.729	4636245.363	1584.92	1584.96	0.04
484491	388435.943	4636245.454	1584.667	1584.7	0.033
484651	388756.699	4635989.658	1568.962	1568.99	0.028
484652	388756.917	4635986.38	1569.152	1569.17	0.018
484653	388757.193	4635982.958	1569.292	1569.32	0.028
484654	388757.492	4635979.579	1569.366	1569.39	0.024
484655	388757.822	4635976.3	1569.4	1569.42	0.02
484656	388758.088	4635973.01	1569.43	1569.44	0.01
484657	388758.324	4635969.664	1569.435	1569.45	0.015
484658	388758.545	4635966.215	1569.406	1569.43	0.024
484659	388758.734	4635962.684	1569.366	1569.4	0.034
484660	388758.927	4635959.111	1569.317	1569.34	0.023
488901	400585.696	4639300.56	1339.183	1339.21	0.027
488902	400584.823	4639303.659	1339.155	1339.22	0.065
488903	400583.96	4639306.816	1339.085	1339.1	0.015
488904	400583.109	4639310.011	1339.014	1339.07	0.056
488905	400582.273	4639313.2	1338.974	1339.03	0.056
488906	400581.488	4639316.186	1338.926	1338.99	0.064
488907	400580.726	4639319.014	1338.85	1338.91	0.06
488908	400579.929	4639321.749	1338.812	1338.84	0.028
488909	400579.11	4639324.527	1338.777	1338.8	0.023
488910	400578.426	4639327.286	1338.686	1338.71	0.024

Point	Easting	Northing	Known Z	Laser Z	Dz
488911	400577.732	4639330.206	1338.613	1338.65	0.037
488912	400576.988	4639333.151	1338.538	1338.58	0.042
489001	400509.263	4639595.455	1336.369	1336.45	0.081
489002	400508.621	4639597.97	1336.38	1336.43	0.05
489003	400507.815	4639600.908	1336.314	1336.35	0.036
489004	400506.907	4639604.223	1336.28	1336.31	0.03
489005	400505.941	4639607.839	1336.264	1336.34	0.076
489006	400504.997	4639611.645	1336.244	1336.26	0.016
489007	400504.126	4639615.499	1336.242	1336.27	0.028
489008	400503.238	4639619.262	1336.239	1336.25	0.011
489009	400502.311	4639622.946	1336.239	1336.25	0.011
489010	400501.375	4639626.588	1336.248	1336.25	0.002
489011	400500.476	4639630.126	1336.239	1336.24	0.001
492021	401159.542	4647665.328	1341.252	1341.28	0.028
492022	401160.572	4647660.621	1341.116	1341.13	0.014
492023	401161.678	4647655.648	1341.014	1341.02	0.006
492024	401162.808	4647650.359	1340.906	1340.93	0.024
492025	401164.091	4647644.803	1340.793	1340.81	0.017
492026	401165.442	4647639.085	1340.668	1340.69	0.022
492027	401166.815	4647633.2	1340.515	1340.53	0.015
492028	401168.184	4647627.251	1340.364	1340.4	0.036
492029	401169.548	4647621.328	1340.232	1340.27	0.038
492030	401170.908	4647615.435	1340.098	1340.14	0.042
492031	401172.215	4647609.546	1339.965	1340.01	0.045
492681	401926.152	4646909.49	1347.609	1347.66	0.051
492682	401924.072	4646911.886	1347.592	1347.64	0.048
492683	401922.029	4646914.28	1347.561	1347.64	0.079
492684	401919.95	4646916.688	1347.549	1347.58	0.031
492685	401917.883	4646919.146	1347.515	1347.57	0.055
492686	401915.826	4646921.65	1347.478	1347.54	0.062
492687	401913.758	4646924.094	1347.478	1347.53	0.052
492688	401911.744	4646926.372	1347.499	1347.55	0.051
492689	401909.785	4646928.605	1347.507	1347.57	0.063
492690	401907.831	4646930.859	1347.5	1347.57	0.07
492691	401905.826	4646933.17	1347.488	1347.52	0.032
	Average Dz	0.032			
	Minimum Dz	-0.025			
	Maximum Dz	0.081			
	Root Mean Square	0.038			
	Std. Deviation	0.020			
	95th Percentile	0.066			

Appendix C

Flight Logs

Date: 04/15/2017	**Aircraft:** N7269T	**Sensor:** 12 SEN 315
Project: Washakie & Whites Valley		**Job #**: 17046
Flight Plan(s): 3699_H300_GSM_Whites_v2.xml 3699_H300_GSM_Washakie_v2.xml		
	Flight 1	**Flight 2**
Wheels Up:	0645	1235
Wheels Down:	1145	1415
Begin Tach:	6817.0	6821.3
End Tach:	6821.3	6823.7
Mobilization Tach:	1.2	1.2
Online Tach:	3.3	1.0
Pilot: Begley	**Operator:** Guenther	
Notes: Afternoon lift ended up being extremely bumpy and data was no good on the 2nd lift.		

Date: 04/16/2017	**Aircraft:** N7269T	**Sensor:** 12 SEN 315
Project: Washakie & Whites Valley		**Job #**: 17046
Flight Plan(s): 3699_H300_GSM_Washakie_v2.xml		
	Flight 1	**Flight 2**
Wheels Up:	0630	N/A
Wheels Down:	1105	N/A
Begin Tach:	6823.7	N/A
End Tach:	6828.4	N/A
Mobilization Tach:	1.95	N/A
Online Tach:	2.75	N/A
Pilot: Begley	**Operator:** Guenther	
Notes: No issues to report. Great conditions this morning.		

Appendix D

SOW

Scope of Work on Master Agreement # AV2406
Acquisition of Aerial Lidar Elevation Data
Whites Valley & Washakie Areas

The State of Utah, Department of Technology Services, Division of Integrated Technology, Automated Geographic Reference Center (AGRC) and partners are contracting with Aero-Graphics, Inc. to acquire, process, and deliver aerial Lidar data and derivative products that meet the specifications described in this Scope of Work, and contracted under Master Agreement #AV2406.

This Scope of Work (SOW) identifies the specific acquisition requirements, production specifications and standards, deliverables, and schedule for Lidar data collection and deliverable data products that adhere to the U.S. Geological Survey (USGS) Quality Level 1 (QL1) Lidar specifications for the entire area defined in this agreement. The Lidar data will be acquired in the Spring of 2017 with leaf-off conditions and no snow on the ground. Pricing will be based on the cost submitted in the bid response to Solicitation #WS16020-Stage 2 for Washakie and Whites Valley project areas by Aero-Graphics, Inc.

1. Lidar Data Products

The lidar data product must adhere to USGS National Geospatial Program (NGP) *Lidar Base Specification Version 1.2* (2014) available at http://pubs.usgs.gov/tm/11b4/. These lidar specifications are required minimum baseline specifications and project deliverables shall meet or exceed USGS QL1, as specified per project area. For any item which is not specifically addressed, the referenced *Lidar Base Specification Version 1.2* will be the required specification authority.

2. Project Areas, Performance Period, and Acquisition Modifications

The State of Utah 2017 Lidar Acquisition Project ("Project") covers portions of Utah shown in Washakie & Whites Valley - Figure 1.png, and are delineated in Washakie & Whites Valley - Attachment 1.zip (Whites_Valley.shp and Washakie.shp).

2.1. Project Area

The Project acquisition areas total approximately 26.2 mi^2 in northern Utah shown in Figure 1. Further explanation of the project areas is explained in Section 2.1.1. For the contracted acquisition areas, the delivered data products must cover at least the spatial extent (footprint) of the acquisition areas delineated in Attachment 1. Any acquisition footprints that extend beyond Attachment 1 are acceptable, and if data is acquired outside these footprints, at least the raw point cloud data shall be provided.

2.1.1. Washakie and Whites Valley

The Washakie area 12.24 mi^2 and Whites Valley area 13.89 mi^2 total approximately 26.2 mi^2. Lidar acquisition in these areas require QL1 specifications.

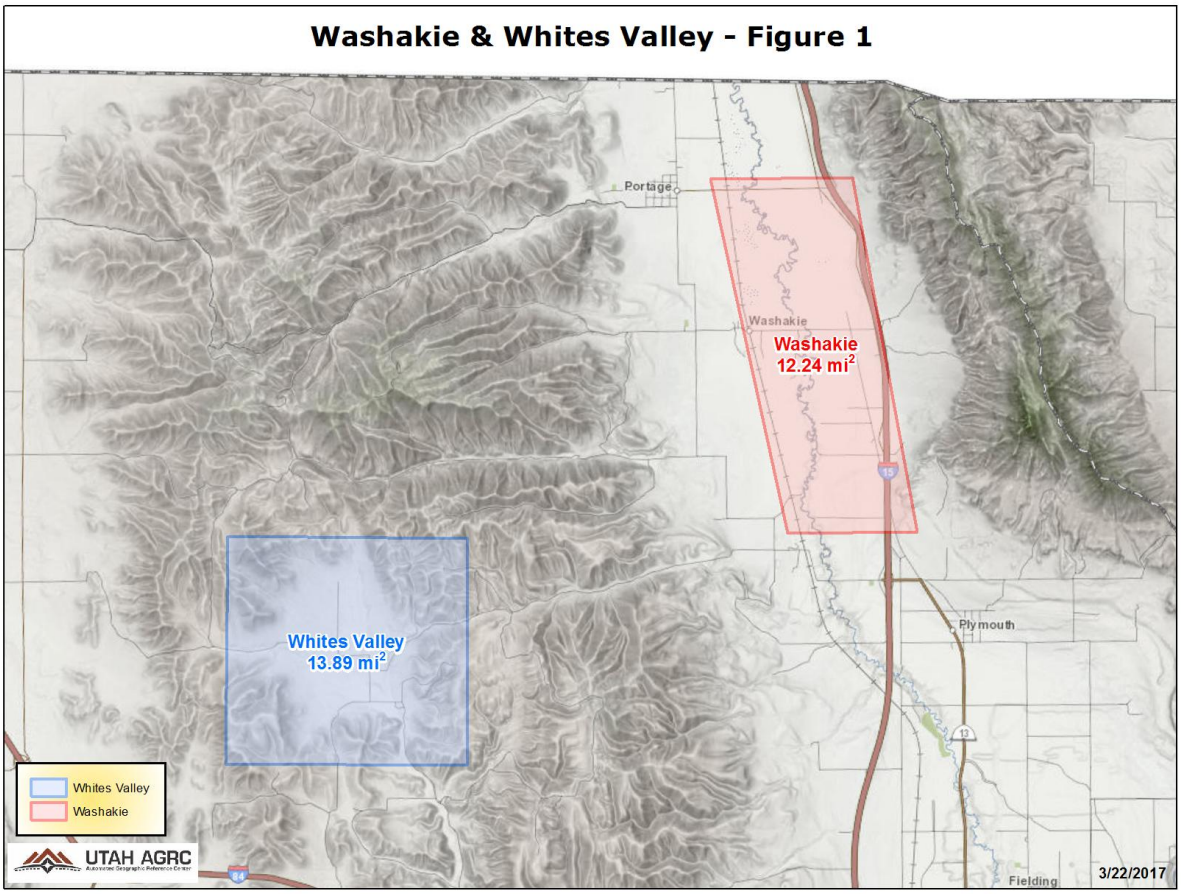


Figure 1: Acquisition Areas

2.2. Performance Period

For the areas described in Section 2.1. the acquisition shall be in the Spring of 2017, maximizing leaf-off conditions, low water levels, and no snow on the ground (such as, may be encountered during October and/or November and later.

2.3. Acquisition Modifications

Any additions or modifications to the lidar project areas (including areas located outside of Utah), by either the State or the other cooperators, will adhere to the data deliverables, standards, specifications criteria, and inspection process described in this SOW. Any changes after initial contracts are negotiated will be made through the agreed upon contract amendment process.

3. Delivery and Quality Assessment and Acceptance Schedule

The Lidar data acquisition schedule will be agreed to by the State and Aero-Graphics, Inc. based on actual weather and on-the-ground conditions after the contract has been approved. This schedule may include a small initial pilot delivery, selected from within the project areas, to ensure that data meets the specifications and conditions of the contract.

A formal data product delivery schedule will be agreed to by AGRC and Aero-Graphics, Inc. after the contract has been approved and may be modified by changes in the acquisition schedule. Lidar acquisition should be timed to ensure the ground is free of snow, ice and standing water, rivers are free of ice and are at a stage of low flow, and lakes and reservoirs are close to the lowest levels of the year. Leaf-off vegetation conditions are preferred and lidar penetration to the ground must be adequate to produce a bare-earth surface DEM that meets or exceeds requirements for vertical accuracy.

The anticipated schedule of delivery and quality assurance is as follows:

- Flight of contracted area for data product.
    - Length of acquisition time to be determined by Aero-Graphics, Inc. in collaboration with AGRC.
- Process and deliver all data products to AGRC for initial inspection and review.
    - AGRC has 30 days to review and submit correction requests.
- Aero-Graphics, Inc. addresses initial review comments and redelivers areas to AGRC for final inspection.
    - Aero-Graphics, Inc. has 20 days to redeliver with corrections.
- AGRC final inspection and review.
    - AGRC has 20 days to review and submit correction requests.
- Aero-Graphics, Inc. addresses final review comments and delivers final and complete data products to AGRC.
    - Aero-Graphics, Inc. has 20 days to redeliver final data product.

If it is not possible to rework the data to correct error(s), a reflight of that area may be required.

3.1. Inspection Schedule

An inspection schedule for quality assurance of all products will be developed between Aero-Graphics, Inc. and AGRC. Aero-Graphics, Inc. shall document its internal quality assurance work as described in Section 6. A review committee designated by AGRC will quality check the lidar products. The USGS National Geospatial Technical Operations Center (NGTOC) will also be used to ensure that the delivered data products meet the requirements of the USGS NGP *Lidar Base Specification Version 1.2* (2014) and The National Map: 3D Elevation Program (3DEP) set forth in this SOW. Deliverables will not be accepted without acceptance by the USGS NGTOC. The inspection period for each initial data product delivery will be up to 30-calendar days; these inspection periods may be concurrent. Review of any redelivery of data with corrections will be completed within 20-calendar days of receipt. If collection conditions necessitate the need for a later acquisition, AGRC, and Aero-Graphics, Inc. can modify this date through a contract amendment. Deliveries will be made to AGRC.

4. Access to Lands and Airspace

Aero-Graphics, Inc. is responsible for applying for and obtaining all required permits, clearances, permissions, etc. for access, over-flight, or intrusion to restricted or otherwise limited ground access and/or airspace, which may be included within the requirement of this project. AGRC can assist with expediting these processes where possible.

5. Data Product Deliverables

See the USGS NGP *Lidar Base Specifications Version 1.2* (2014) (http://pubs.usgs.gov/tm/11b4/) "Data Processing and Handling" section and Section 15 "Cited Specifications and Standards" for requirements on the processing and handling of the lidar data.

5.1. Metadata

Descriptive information about the project to include textual reports, graphics, supporting shapefiles, and Federal Geographic Data Committee (FGDC) compliant metadata files are required. See National Spatial Data Infrastructure (NSDI) Content Standards for Digital Geospatial Metadata (FGDC, 1998) and Lidar Base Specifications Version 1.2 (USGS, 2014) "Metadata" section for metadata requirements for this project.

A current Product Characterization Report of the instrument used shall be included in the Project History Report/Folder (Section 6) as a deliverable.

5.2 Raw Point Cloud

Raw point cloud deliverables shall include or conform to the following procedures and specifications:

- No classifications are required; however, Overage (overlap) and Withheld Flags will be properly set.
- All collected points, fully calibrated, georeferenced, and adjusted to ground, organized and delivered in their original swaths, one file per swath, one swath per file.
- If production processing required segmentation of the swath files, the requirements listed in the section "Swath Size and Segmentation," shall be met.
- Fully compliant LAS Specification version 1.4, Point Data Record Format 6, 7, 8, 9, or 10.
- If collected, waveform data in external auxiliary files with the extension .wdp. See the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Correct and properly formatted georeference information as Open Geospatial Consortium (OGC) well known text (WKT) in all LAS file headers.
- GPS times recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values, normalized to 16-bit. See the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- A report of the assessed relative vertical accuracy of the point cloud (smooth surface repeatability and overlap consistency). Relative vertical accuracy requirements are listed in table 2. Raw swath point cloud data shall meet the

required accuracy levels before point cloud classification and derivative product generation.

- A report of the assessed absolute vertical accuracy (NVA only) of the unclassified lidar point data in accordance with the guidelines set forth in the Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). Absolute vertical accuracy requirements using the ASPRS methodology for the raw point cloud are listed in table 4. Raw swath point cloud data shall meet the required accuracy levels before point cloud classification and derivative product generation.

5.3 Classified Point Cloud

Classified point cloud deliverables shall include or conform to the following procedures and specifications:

- All project swaths, returns, and collected points, fully calibrated, adjusted to ground, and classified, by tiles. Project swaths exclude calibration swaths, cross-ties, and other swaths not used and not intended to be used, in product generation.
- Fully compliant LAS Specification version 1.4 Point Data Record Format 6, 7, 8, 9, or 10.
- If collected, waveform data in external auxiliary files with the extension .wdp. See the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Correct and properly formatted georeferenced information as OGC WKT included in all LAS file headers.
- GPS times recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse.
- Intensity values, normalized to 16-bit. See the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) for additional information.
- Tiled delivery, without overlap, using the project tiling scheme.
- Classification, as defined below.

Code/Class	Description
1	Processed, but unclassified
2	Bare earth
7	Low noise
9	Water
10	Ignored ground (near a breakline)
17	Bridge decks
18	High noise

5.4 Bare-Earth Surface (Raster DTM), Hydro-Flattening, and Breaklines

Bare-earth deliverables include the following:

- Bare-earth DEM with hydro-flattening (see section 5.4.1 Hydro-Flattening).
- Cell size no greater than 0.5 meters and no less than the design Nominal Pulse Spacing (NPS) for QL1 collections.
- Delivery in an industry-standard, GIS-compatible, 32-bit floating point raster format (ESRI Grid preferred).
- Georeference information shall be included in each raster file.
- Tiled delivery, without overlap, using Project Tiling Scheme (section 7).
- DEM tiles will show no edge artifacts or mismatch. A quilted appearance in the overall project DEM surface, whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions, will be cause for rejection of the entire deliverable.
- Void areas shall be coded using a unique 'NODATA' value. This value shall be identified in the appropriate location within the raster file header or external support files (for example, *.aux*).
- A report on the assessed absolute vertical accuracy (NVA and VVA) of the bare-earth surface in accordance with the guidelines set forth in the "Positional Accuracy Standards for Digital Geospatial Data" (American Society for Photogrammetry and Remote Sensing, 2014).
- The following thresholds represent the minimum vertical accuracy requirements using the NDEP/ASPRS methodology:
    - NVA ≤ 19.6 cm, 95% Confidence Level (≤10 cm $RMSE_z$)
    - VVA ≤ 29.4 cm, 95% Confidence Level (≤10 cm $RMSE_z$)
    - All Quality Assurance/Quality Control (QA/QC) analysis materials and results are to be delivered to the State.
- Depressions (sinks), natural or man-made, are not to be filled (as in hydro-conditioning and hydro-enforcement).
- Permanent islands 1 acre or larger shall be delineated within all water bodies.

5.4.1. Hydro-Flattening

- Hydro-flattening shall be applied to all water within the main channels of rivers and streams, along with all water bodies or impoundments, natural or man-made, that are larger than 2 acres in area (approximately equal to a round pond 350 feet in diameter), and to all streams that are nominally wider than 100 feet, and to all non-tidal boundary waters bordering the project area regardless of size are to be hydro-flattened within the delivered DEMs. Refer to *Lidar Base Specifications Version 1.2* (USGS, 2014) "Hydro-Flattening" section for further explanation.
- Hydro-flattened water bodies (lake and ponds) are leveled at a single elevation and streams and rivers are conditioned for continuous downhill flow.
- Hydro-flattened/Bare-earth surface must cover the entire water body and leave no holes in the center. This can be done with interpolation and does not require lidar collection over the entire water body.
- All hydro-flattened areas should have pleasing aesthetic appearance.
- The methodology used for hydro-flattening is at the discretion of Aero-Graphics, Inc. Refer to the "Digital Elevation Model Hydro-Flattening" section and "Appendix 2. Hydro-Flattening Reference" in the Lidar Base

Specifications Version 1.2 for detailed discussions concerning hydro-flattening.

- The bare-earth DEM data should keep intact all road culverts and similar features, regardless of size, defined as having earth between the road surface and the top of the structure.
- Bridges are required to be removed from the bare-earth DEM. Streams and rivers should be continuous at bridge locations.

5.4.2. Breaklines

All breaklines used for hydro-flattening are to be delivered in a shapefile and/or geodatabase format as PolylineZ or PolygonZ feature classes. See *Lidar Base Specifications Version 1.2* (USGS, 2014) "Breaklines" section for breakline requirements.

5.5 First Return Surface (Raster DSM)

First-return deliverables include the following:

- First return DEM (for example, highest hit).
- Cell size no greater than 0.5 meters and no less than the design Nominal Pulse Spacing (NPS) for QL1 collections.
- Delivery in an industry-standard, GIS-compatible, 32-bit floating point raster format (ESRI Grid preferred).
- Georeference information shall be included in each raster file.
- Tiled delivery, without overlap, using Project Tiling Scheme (Section 7).
- DEM tiles will show no edge artifacts or mismatch. A quilted appearance in the overall project DEM surface, whether caused by differences in processing quality or character between tiles, swaths, lifts, or other non-natural divisions, will be cause for rejection of the entire deliverable.

Void areas shall be coded using a unique 'NODATA' value. This value shall be identified in the appropriate location within the raster file header or external support files (for example, *.aux*).

5.6 Intensity Images

- 0.5 m resolution intensity images in 8-bit grayscale GeoTIFF format for QL1 collections.

6. Contractor's Project History Report/Folder

Aero-Graphics, Inc. will compile and provide a project history report/folder upon conclusion of the lidar acquisition. This folder will be used by AGRC in the inspection process for the lidar. The report/folder, will contain, at a minimum, the following:

- Methods
  - A record of field work procedures.

  - Data derivation and adjustments.
  - Processing report detailing calibration, classification, and product generation procedures including methodology used for breakline collection and hydro-flattening.
  - Any problems encountered and solutions used in resolving such problems.
- Correspondence and records
  - The Statement of Work (SOW) between AGRC and Aero-Graphics, Inc.
  - All production guidance received from AGRC to include all written guidance from telephone conferences, emails, or contractual modifications, or any other source.
  - Lidar acquisition methods; results; Aero-Graphics, Inc. accuracy assessments, including internal reproducibility and absolute accuracy; file formats; file-naming schemes; and tiling schemes.
- Flight information
  - Aircraft trajectory log
    - SBET files (smooth, best, estimated trajectory) detailing aircraft position (easting, northing, elevation), angle, rotation (heading, pitch, and roll), and GPS time, recorded at regular intervals of ≤ 1 second. May include additional attributes (ASCII text or shapefile and .dbf format).
  - Statistical report summarizing the results of the airborne GPS adjustment and the overall accuracy of the adjusted IMU data.
  - Collection report detailing mission planning and flight logs.
- Control
  - Survey Report detailing the collection of control and reference points used for calibration and QA/QC.
  - The documentation for the identity, published position, and measured position of all existing National Geodetic Survey (NGS) marks used for reference stations.
- Quality Assurance/Quality Control (QA/QC)
  - QA/QC Reports (detailing the analysis, accuracy assessment and validation of:
    - The point data (absolute, within swath, and between swath)
    - The bare-earth surface (absolute)
    - Other optional deliverables as appropriate
  - Quality control procedures and results.
  - All internal quality control checklists.
  - Internal quality control error calls and the corrective actions taken to correct the error(s).
  - All Aero-Graphics, Inc. QA validation reports/error reports and accuracy reports, generated from internal software QA programs demonstrating that the data meets requirements as stated in the SOW.

7. Tiling Scheme

A single non-overlapped tiling scheme for both data products will be established and agreed upon by AGRC and Aero-Graphics, Inc. before each collection. This scheme will be used for ALL tiled deliverables.

Tiling for the Lidar deliverables will be based on the U.S. National Grid and should be named according to the U.S. National Grid System based on the SW corner (ex. 12TVK060160). Tiles will be 2,000-meter x 2,000-meter tiles with the exception of tiles around the periphery of the project area that are better suited for 1,000-meter x 1,000-meter tiles. 1,000-meter x 1,000-meter tiles will be used for the .las point cloud files.

- Tile size is required to be an integer multiple of 0.5 meters for raster deliverables.
- Tiles are required to be sized using the same units as the coordinate system of the data.
- Tiles are required to be indexed in X and Y to an integer multiple of the tile's X-Y dimensions.
- All tiled deliverables will conform to the project tiling scheme, without added overlap.
- Tiled deliverables will edge-match seamlessly and without gaps.

7.1. Void Areas

The extent of lidar coverage over the project area shall be sufficient to ensure void areas do not exist within the project area. Void areas within delivered tiles and within the project area are not acceptable.

8. Delivery Medium and Format

Deliverables shall be delivered on USB3 compatible portable hard drives using an uncompressed and unencrypted NTFS file system. Delivery tiles shall be accompanied by an index shapefile, of the tiles delivered, suitable for loading into ArcMap.

All data and products associated with contract deliverables will meet or exceed relevant National Standard for Spatial Data Accuracy (NSSDA) standards. See *NSDI Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy* (FGDC, 1998).

At the completion of the project, after all deliverables have been accepted by AGRC, Aero-Graphics, Inc. will deliver hard drives containing all the finalized deliverables for the project, and become the property of the State of Utah.

9. Data Acquisition Requirements and Collection Conditions

Refer to *Lidar Base Specification Version 1.2* (2014) for the following specifications:

- Acquisition requirements
- Collection conditions

9.1. Additional Data Acquisition Requirements

- Instrument calibrated for every mission.
- Flight plans are parallel flight lines with a cross-tie at/and or near the end of each project flightlines.
- Flight plan considers requirements for point density, terrain, PDOP (positional dilution of position), and Geomagnetic *Kp* Index (see http://www-app3.gfz-potsdam.de/kp_index/description.html).

- The intensity values (signal strength) of each return pulse will be recorded in the LAS, in their files native radiometric resolution.
- In order to prevent clustering effects and ensure uniform densities throughout the data set, a regular 1 x 1 meter grid will be laid over the data. At least 90% of the cells in the grid shall contain the requisite number of points per square meter (ppsm).

10. Standards, Specifications, and Requirements

Refer to *Lidar Base Specification Version 1.2* (2014) for the following specifications:

- Quality Level 1 and Quality Level 2 Specifications
- Vertical Accuracy Requirements
- Positional Accuracy Validation
- Relative Accuracy Requirements
- Completeness of coverage

10.1. Projection and Mapping Units

- Projection (Coordinate System): Universal Transverse Mercator (UTM) Zone 12, NAD 83, Meters; NAVD88, Meters (NAD_1983_2011_UTM_Zone_12N).
- Mapping Units: Meters (UTM).
- Vertical Reference: Orthometric Heights, Meters.
- WKID: 6341 Authority: EPSG

10.2. Datums

All data collected must be tied to the datums listed below:

- Horizontal Datum:
  - North American Datum of 1983 / High Accuracy Resolution Network adjustment (NAD 83 [2011] / HARN) required.
- Vertical Datum:
  - North American Vertical Datum 1988 (NAVD88), using latest geoid model available from the NGS (for example, GEOID12B). All vertical units will be measured in meters.
- Geoid Model:
  - The most recent NGS approved geoid model is required to perform conversions from ellipsoidal heights to orthometric heights.

10.3. Usability

- Files shall have consistent internal formats.
- Aero-Graphics, Inc. shall propose all details of file names and file formats that are not specified here. Proposed names and formats must be approved by AGRC.
- Files may be gzip or zip compressed. Use of compression shall be lossless and uniform across a given data layer.
- GIS data (ESRI grids, shapefiles) shall have complete and correct associated projection, metadata, and sidecar files.
- All files must be readable and free of malicious code.

10.4. GPS Procedures

10.4.1. GPS Measurements

All GPS measurements shall be made with dual frequency Global Navigation Satellite System (GNSS) receivers with GLONASS. All GPS measurements shall be made during periods with PDOP ≤ 3.0 and with at least six satellites in common view of both a stationary reference receiver and the roving receiver.

10.4.2. Stationary Reference Receivers

Stationary reference receivers shall be located at existing NGS marks or at new marks. In the case of an existing mark, its location shall be verified by processing one GPS session of at least two hours duration and comparing the computed position with the position published by NGS. Each new mark shall be located by tying to one or more NGS Continuously Operating Reference Stations (CORS) by static GPS methods. If the distance to the nearest CORS is less than 80 km, use at least two independent GPS sessions, each at least two hours long. If the distance to the nearest CORS is greater than 80 km, use at least two sessions each at least four hours long.

10.4.3. GPS Reference Receivers

At least two GPS reference receivers shall be in operation during all lidar missions, sampling positions at ≥1 Hz. The roving GPS receiver in the aircraft shall sample positions at ≥ 2 Hz. Differential GPS baseline lengths shall be no longer than 30 km. Check Points, Ground Control Points (GCPs), or ground survey points used for both survey calibration and assessment of absolute vertical accuracy, shall be established using GPS and (or) other techniques that are expected to result in accuracies of 1.5 cm ($RMSE_z$) or better. Strongly clustered GCPs are useful, perhaps even desirable, for calibration. Vertical accuracy shall be assessed by calculating and averaging the distances between a subset of at least 30 GCPs that are not clustered and a surface interpolated from lidar first returns. At least 20% of flight line swaths should contain points in this subset and the maximum distance between these GCPs should be no less than one-half the maximum distance across the survey area.

10.4.4. Project History Report/Folder

Aero-Graphics, Inc. Project History Report/Folder (Section 6) shall document the identity, published position, and measured position of all existing NGS marks used for reference stations. The locations of new marks shall be described, along with their measured positions and the identity and published positions of CORS to which their locations were tied. The report shall describe the technique(s) used to establish GCPs and document the positions and residuals of all GCPs used to evaluate survey accuracy.

10.5. Ground Control

Two types of vertical accuracy GCP (or ground surveyed points) will be collected by Aero-Graphics, Inc. for this project: Control Points and Check Points. Refer to NSSDA guidelines, Lidar Base Specifications Version 1.2 (USGS, 2014) “Collection” section, and

ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data (ASPRS, 2004) “2.3 Selecting and Collecting Check Points” section for Check Point placement in land cover classes and guidelines on Check Points.

- The above two types of ground control will be clearly labeled and delivered as separate shapefiles to the State.

10.6. Supplemental Ground Control

Differentially corrected or real time GPS network (RTK) GPS ground control used to supplement the airborne GPS positional adjustment shall be stored on portable media, in a non-proprietary format mutually agreeable to AGRC and Aero-Graphics, Inc. Ground control is the responsibility of Aero-Graphics, Inc.

10.6.1. Utah Reference Network

AGRC maintains The Utah Reference Network (http://gis.utah.gov/#gps) of over 90 GPS VRS RTK stations and will facilitate use of this network upon request of Aero-Graphics, Inc.

11. Data Release, Data Use and Distribution Rights

11.1. Data Release

Aero-Graphics, Inc. will not release data produced in each project plan, to any other party or entity without approval by AGRC, prior to the processing, loading, incorporation, and AGRC’s final acceptance of data products.

11.2. Data Use and Distribution Rights

After final acceptance has been made, all deliverable data and documentation will be free from restrictions regarding use and distribution (the State of Utah and partners require unrestricted rights to all delivered data and reports that are placed in the public domain). Data and documentation provided under this project plan shall be in the public domain and freely distributable by Federal, State, and local government agencies.

13. Project Communication

13.1. Production Status Reports

Aero-Graphics, Inc. shall provide weekly status reports for all work on projects to AGRC's Project Manager. Reports will include detailed information regarding the work accomplished for each production phase. An online website may be used to provide status information.

13.2. Acquisition Reports

Aero-Graphics, Inc. shall provide regular progress updates to AGRC's Project Manager throughout the data acquisition process.

- Update frequency shall be based upon the collection period, but no less than once a week.
- Reports shall include shapefiles representing the geographic extent of the acquired data.
- Updates shall commence at acquisition onset and shall continue until acquisition is complete.

13.3. Initial Project Meeting

An initial project meeting between AGRC and Aero-Graphics, Inc. will be scheduled after each project request. This meeting will ensure that both AGRC and Aero-Graphics, Inc. 1) understand the requirements necessary to produce the deliverables, 2) review source data, and 3) make any final adjustments to technical guidance.

13.4. Teleconference

Aero-Graphics, Inc. will teleconference regularly (weekly or as needed) with the State to discuss status, production, and technical issues during a project.

14. Delivery Date and Timely Completion

14.1. Delivery Date

AGRC and Aero-Graphics, Inc. will agree in writing to a delivery schedule for Lidar products. Deliver for all final Lidar products, including any redeliveries because of quality assurance rejection, is no later than September 31, 2017. Aero-Graphics, Inc. shall not exceed this date without agreement to a new date from AGRC. Any request for modifications of the final delivery date must be received 30 days prior to the expiration of the original date. Request will only be considered for reasons outside Aero-Graphics, Inc. control, such as unforeseen weather changes.

14.2. Timely Completion

The payment schedule shall include penalties for late delivery of products. The payment schedule will be based on 40% of the total project cost after completion of the lidar

acquisition flights. After the completion of processing and corrections based on the quality assurance review by AGRC, and delivery of the final product(s) to AGRC, payment will be made as follows. If delivered on time as specified in the contract, another 30% of the total project cost will be paid. There will be a 30% holdback that will be paid after that final delivery of all data and required reports and metadata deliveries are confirmed by AGRC. If the final product(s) is not delivered on the schedule specified, there will be a 3% (of the total bid) penalty for each week the product delivery is delayed.

15. List of Cited Specifications and Standards

Specifications for the acquisition of Lidar and deliverables not explicitly outlined above must adhere to the required specifications in the following documents:

Proponent Agency/ Organization	Name	Published Date	Website
American Society for Photogrammetry and Remote Sensing (ASPRS)	LAS Specification Version 1.4	July 2011	http://www.asprs.org/a/society/committees/standards/LAS_1_4_r13.pdf
U.S. Geological Survey, National Geospatial Program (USGS NGP)	Lidar Base Specifications Version 1.2	2014	http://pubs.usgs.gov/tm/11b4/
Federal Geographic Data Committee (FGDC)	National Spatial Data Infrastructure (NSDI) Geospatial Positioning Accuracy Standards,	1998	http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3
National Digital Elevation Program (NDEP)	NDEP Guidelines for Digital Elevation Data	May 2004	http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf
FGDC	NSDI Content Standard for Digital Geospatial Metadata	1998	http://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/base-metadata/v2_0698.pdf
Federal Emergency Management Agency (FEMA)	Guidance for Flood Risk Analysis and Mapping: Elevation Guidance	Nov. 2015	http://www.fema.gov/media-library-data/1449865619080-7895ba81cd9b94c6d9ac125bb1958e0c/Elevation_Guidance_Nov_2015.pdf
FGDC	United States National Grid	December 2001	http://www.fgdc.gov/standards/projects/FGDC-standards-projects/usng/fgdc_std_011_2001_usng.pdf

Production Guidance

From: Rick Kelson [mailto:rkelson@utah.gov]
Sent: Monday, April 17, 2017 4:33 PM
To: Casey Francis <cfrancis@aero-graphics.com>
Cc: Steve Bowman <stevebowman@utah.gov>; Bernie Doud <bdoud@aero-graphics.com>
Subject: Re: Washakie & Whites Valley - PROGRESS UPDATE - 4/17/17

Works for me. Thanks for providing this. You can invoice us for 40%. When you send it to dtsreceiving@utah.gov provide the PO # DO - 170000000004673 in the email subject line.

Remember to use NAD83 (2011). Also lets change the DEM deliverables from ESRI Grid Format to Erdas Imagine files (.img)

Rick Kelson

Utah AGRC
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