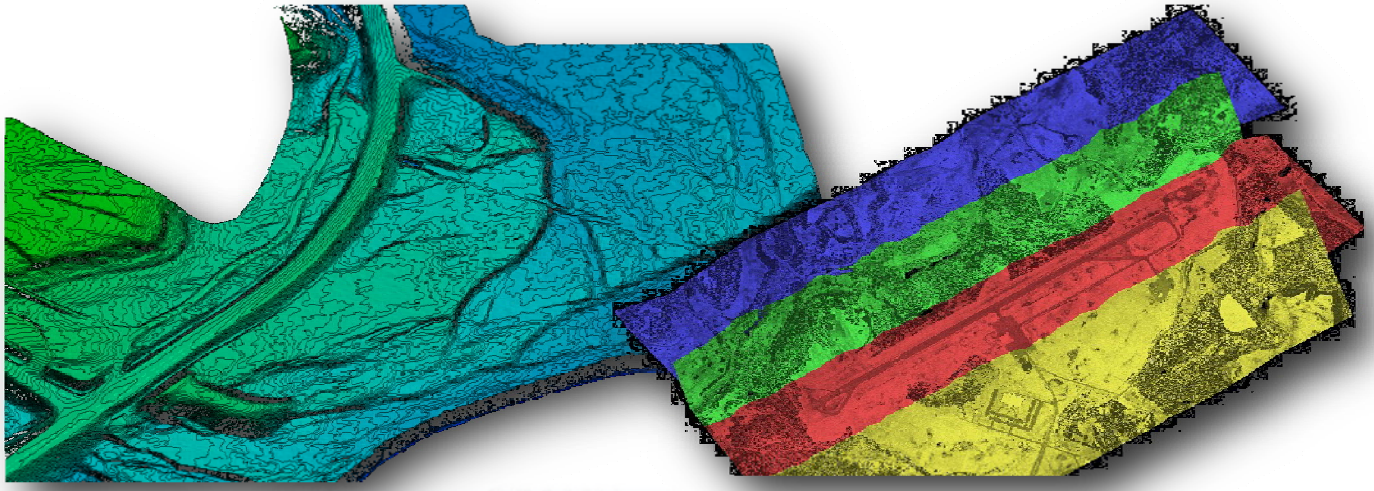
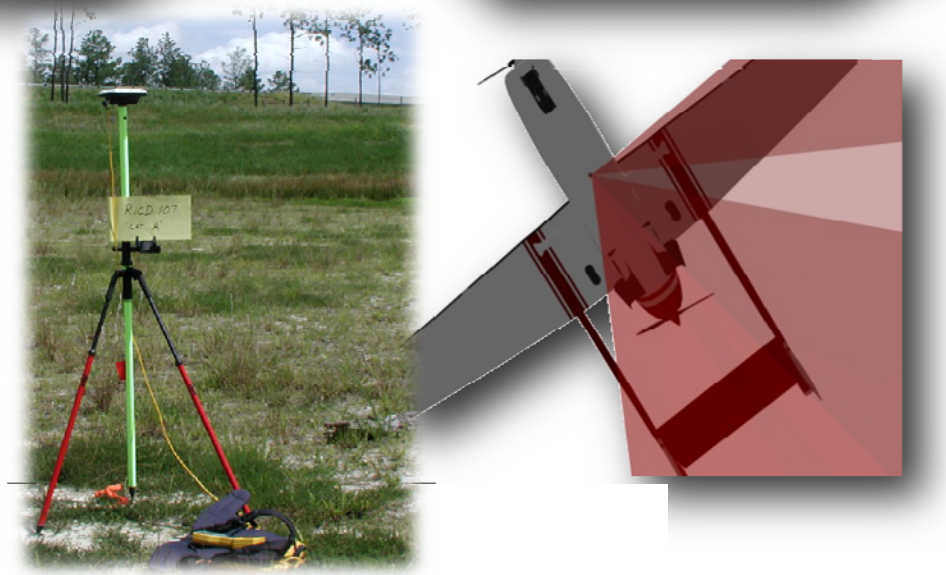
Region 8- Granite 2-ft Area

GRANITE COUNTY, MONTANA

Accuracy Assessment and QC Report

SEPTEMBER 2012





Submitted by:

BakerAECOM
An Integrated Production Team

TABLE OF CONTENTS

1. INTRODUCTION

BakerAECOM performed an independent accuracy assessment and quality control review of the bare-earth randomly spaced LIDAR data collected and processed in 2 areas in Region 8 by Photo Science Inc. The project was carried out using the specifications and the guidelines provided in the following documents.

1) FEMA's Flood Hazard Mapping Program; Guidelines and Specifications for Flood Hazard Mapping Partners - Appendix A, Guidance for Aerial Mapping and Surveying,

2) FEMA's Memorandum for Regional Risk Analysis Branch Chiefs, Procedure Memorandum No. 61: Standards for LiDAR and Other High Quality Digital Topography, Effective Date September 27, 2010;

3) U.S. Geological Survey (USGS), National Geospatial Program, LiDAR Guidelines and Base Specification, vers. 13, Effective Date February 22, 2010;

4) American Society for Photogrammetry and Remote Sensing (ASPRS), ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, vers. 1.0, May 24, 2004.

5) National Geodetic Survey (NGS), NOAA Technical Memorandum NOS NGS-58, Guidelines for establishing GPS-Derived Ellipsoid Heights, (Standards: 2cm and 5 cm), Vers. 4.3., November, 1997.

This document presents the results of the accuracy assessment and quality review.

1.1 PROJECT SITE AND PARAMETERS

The following table provides a summary of the project area and related parameters.

Table 1 Parameters for Region 8 Project Sites

PROJECT SITE PARAMETERS	GRANITE, MT
Nominal Pulse Spacing (NPS)	< 1 m
FEMA Project Area (Sq. Miles)	2.7
Acquisition Area (Sq. Miles)*	3
Equivalent Contour Accuracy	2 ft
Bare Earth Processing Area (Sq. Miles)	<1

*The Acquisition Area contains the original FEMA Project Area and the required 100 meter buffer as defined in PM No. 61.

The study area has been shown in Fig 1.

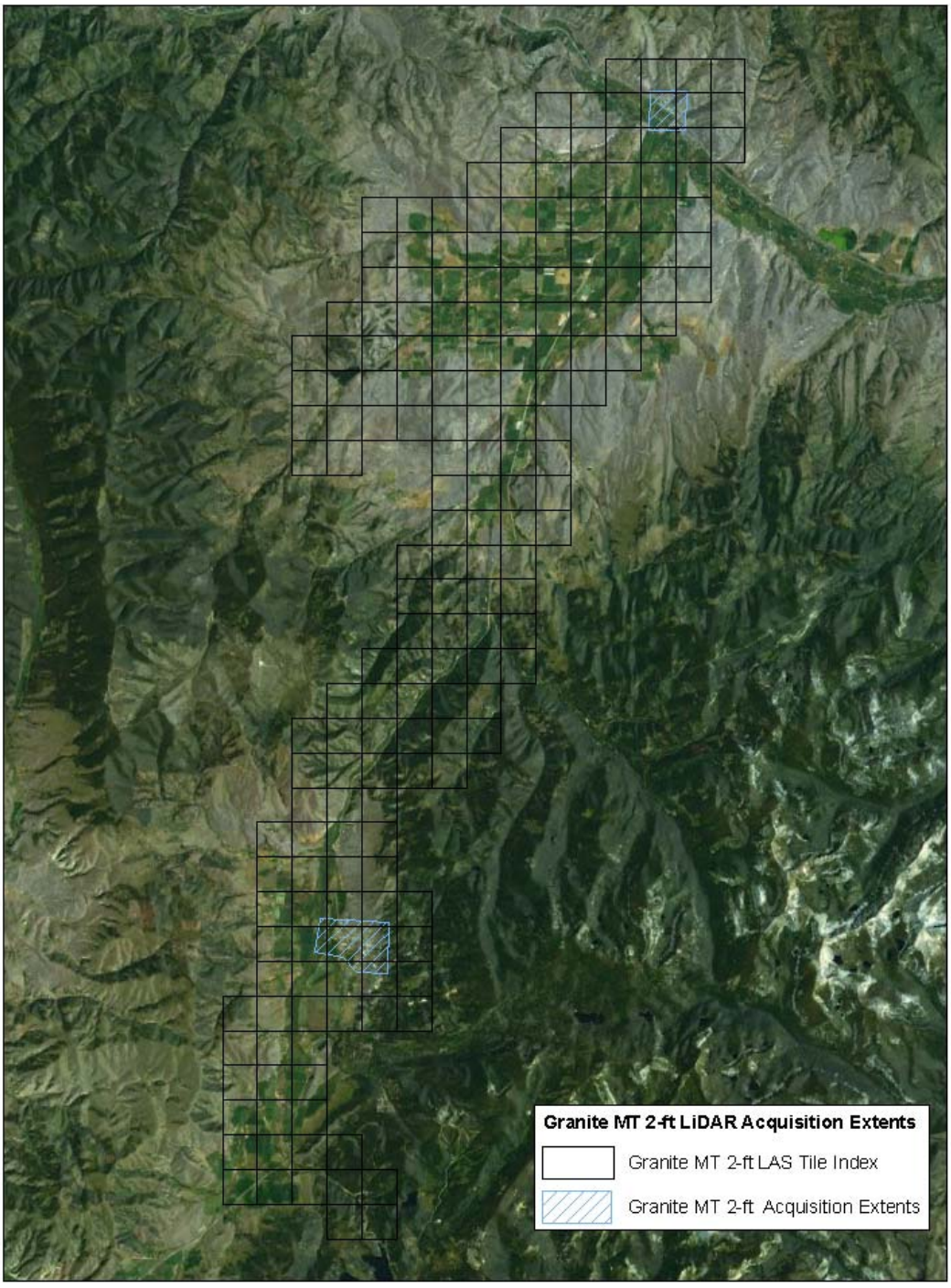


FIG 1: PROJECT SITE MAP

1.2 LiDAR Preliminary Processing (Acquisition Area)

LiDAR Preliminary Processing was performed by Photo Science Inc for the entire acquisition area. Preliminary processing involves filtering the data for noise, differentially correcting, and assembling data into flight lines by "return layer." This processing computes the laser point coordinates from the independent data parameters: scanner position, orientation parameters, scanner angular deflection, and the laser pulse time of flight, or slant range. The deliverable of the preliminary processing task is a fully calibrated point cloud data set, unclassified, which has been tiled and prepared for delivery in LAS v. 1.2 format.

1.3 LiDAR Post- Processing (Bare Earth Area)

LiDAR Post-Processing consists of classifying the LiDAR data's first and last return data points to remove vegetation and buildings. This process is restricted to the floodplain areas as defined by the Bare Earth Processing Areas. Points were filtered, and those representing above ground features (such as trees and buildings) have been classified "out" to obtain points that represent the ground surface. Acceptable data with voids (e.g., water or low near infrared reflectivity, such as freshly laid asphalt) are excluded from the final data.

The deliverable of the post-processing task is a classified point cloud delivered in full compliance with LAS classes:

1	processed, but unclassified
2	bare-earth ground
7	noise
9	water
10	ignored
11	withheld (all points not identified as "withheld" are to be classified)
12	Overlap (Shall not be used)

1.4 Hydrologically-Enforced Water Bodies

Hydro break lines were compiled at a minimum, for inland ponds and lakes that are 2 acres or larger; for inland streams with a nominal width of 100 feet or greater; and for tidal waters, such as oceans, seas, gulfs, bays, inlets, salt marshes, and very large lakes. FEMA will use this break lines to generate hydrologically-enforced products.

1.5 Breaklines

As part of the terrain deliverable, topologically structured, 3-dimensional (3-D) hydrology coverage in ESRI personal geodatabase format created from newly generated 3-D breaklines is required. The primary function of the hydrology dataset is to supplement and constrain TINs created from the LIDAR data; however it is also provides additional benefits to the engineers for hydrologic and hydraulic (H&H)

modeling. Because LIDAR data contains only points, the ability of a LIDAR-only terrain model to capture detailed linear features in their precise 3-D location is limited in some locations.

1.6 Survey for Check Points

To perform accuracy assessments of the LiDAR data, BakerAECOM acquired survey field checkpoints.

The following table lists the project site and the number of check points acquired.

Table 2 Check Point Survey for QA/QC

	Granite, MT
Acquisition Area (square miles)	3
FVA Check Points*	25
Bare Earth Processing Area (square miles)	<1
SVA Check Points (weeds and crops)**	4
SVA Check Points (brush and trees)	4
SVA Check Points (forested)	4
SVA Check Points (urban)	4
Total Number of Check Points	**41**

***FVA – Fundamental Vertical Accuracy**
****SVA – Supplemental Vertical Accuracy**

1.7 QA/QC Process

As part of the LIDAR acquisition proposed through Task Order HSFEHQ-10-J-0010, BakerAECOM performed the following QA/QC efforts under two mile stones:

Milestone 1 – LiDAR data QA/QC for acquisition area

Milestone 2 – LiDAR data QA/QC for processing area

2. MILESTONE 1 – LIDAR DATA QA/QC FOR ACQUISITION AREA

2.1 PROJECT BACKGROUND INFORMATION

The project background info for Granite is given in Table 3.

Table 3 Project Background Info (All Predefined Information)

PROJECT AREA	SQUARE MILES
Points Spacing	1M
Point Density	1.34 average
Multiple Returns	Yes
Altitude	1375m
Overlap	30%
Pulse Rate	70 KHz
Scan Freq	36 Hz
Desired Resolution	0.885 m
Cross Track Resolution	0.885 m
Down Track Resolution	0.885 m
Points / Square Meter	1.34 m2
ASPRS Classification Scheme	Class 1 = Unclassified; and Class 11 = Withheld

Upon receipt of milestone 1 deliverables from Photo Science Inc, BAKERAECOM performed the inventory of the deliverables based on the check list given in Table 4.

Table 4 Milestone 1 Check List

	NOT DELIVERED	PARTIAL DELIVERY	COMPLETE DELIVERY	COMMENTS
Pre-flight Operations Plan (Table 4.1, PM 61 Page 21)			X	
Pre-flight Review Checklist (PM 61 Page 25)			X	
Field Survey Control Report in accordance with FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying; Sec. A.6.5, Page A-29.			X	
Post- flight Aerial Survey and Calibration Report (Table 4.2, PM 61 Page 22)			X	
Post-flight Review Checklist (PM 61, Page 25)			X	
Checklist for Aerial Acquisition Report (PM 61, Page 26)			X	

	Not Delivered	Partial Delivery	Complete Delivery	Comments
Macro Review of Fully Calibrated Raw Point Cloud (Table 4.3, PM 61, Page 23)			X	
SBET File (Smoothed Best Estimate of Trajectory)			X	
All Raw Range Files (.range)				
Fully calibrated, unclassified point cloud data in LAS v 1.2 format in compliance with USGS LiDAR Guidelines and Base Specification, v13.			X	
Raw Flight Data Path Screen Shots Showing Data Coverage			X	
Tiling Scheme used as a Shapefile with tile names			X	
Milestone 1 MetaData			X	

2.2 Survey Related

The QA/QC process for survey control was performed based on the check list given in Table 5.

Table 5 Control Points used in Data Acquisition

Control Points used in Data Acquisition	
1. Check survey report for completeness.	Yes
2. Check proper order, distribution, type and stability of NGS NSRS stations, both horizontal and vertical.	Yes
3. Check baseline lengths to determine if proper network stations have been set up, local, secondary, primary, etc.	Yes
4. Check each baseline vector has been observed twice and to agree to 5 cm vertically.	Yes
5. Check processing computation results for outlying vectors, large residuals, observations failing tests, etc.	Yes

2.3 COMPLETENESS OF DATA – VISUAL

Examination of Pre-flight Operations Plan as given in Table 6.

Table 6 Pre-flight Operations Plan

ITEM	CONTENT	FORMAT	PASS/FAIL/MINOR	COMMENTS (COMPLETED/NOT COMPLETED)
Flight Operations Plan	Planned flight lines – sufficient coverage, spacing and length		Pass	
	Planned GPS stations		Pass	
	Planned ground control- sufficient to control and boresight.		Pass	
	Planned Airport location		Pass	
	Calibration plan		Pass	
	Planned Sensor setting and altitude		Pass	
	Procedure for tracking, executing and checking reflights.		Pass	
	Type of Aircraft and use of ABGPS		Pass	
	Project design supports accuracy requirements.		Pass	
	Project design supports diff land cover and terrain.		Pass	

Examination of Post-flight Aerial Acquisition and Calibration Reports as given in **Table 7.**

Table 7 Post Flight Aerial Acquisition and Calibration Report

ITEM	CONTENT	FORMAT	REPORTS INCLUDED	COMMENTS
GPS base station info	Base station name	ESRI shape file along with attributes.	Yes	
	Latitude& Longitude			
	Base Height,			
	PDOP			
	Map of location			
GPS and IMU processing summary	Maximum horizontal and vertical GPS variance	MS Word/Excel report	Yes	
	GPS separation plot			
	Altitude plot			
	PDOP plot			
	Plot of GPS base station from base station.			
Coverage	Verification of Project coverage	ESRI shape file	Yes	
Flight lines	As flown trajectories	ESRI shape file	Yes	
	Calibration lines			
Flight logs	Pilot, Operator name	MS Word/Excel	Yes	
	AGC switch setting			
	LASER Pulse			
	Mirror rate			
	Field of view			
	Date			
Control	Ground control and Base station layouts	ESRI shape files	Yes	
Data Verification/QC	Description of Data verification QC process	MS Word/Excel/Pdf	Yes	
	Results of Verification and QC steps			

Examine completeness of data on the following and summarized in Table 8:

- Naming convention
- File format
- Vertical and Horizontal coordinate system
- Classification
- Georeferencing

Table 8 Completeness Table

LIDAR DTM AND COMPLETENESS/USABILITY ACCEPTANCE	CHARACTERISTICS	METHOD OF CHECKING
Format and post spacing of LiDAR Mass Points	.LAS with 1.34 m/ sq m	Automatic
Units - Horizontal	U.S. Survey Feet	Automatic
Units - Vertical	U.S. Survey Feet	Automatic
Datum - Horizontal	NAD 83	Automatic
Datum - Vertical	NAVD 88, processed with Geoid03	Automatic
Classification used	Class 1 = unclassified; Class 11 = Withheld	Automatic
Flight lines	Flight lines flown as planned with 30-% overlap between flight swaths, correct altitude (1375' above mean terrain), PDOP < 4; no holidays; periodic, local, calibration checks.	Visual
Filename and Organization	Tiling scheme and 5000 X 5000 ft	Visual
Georeferencing	Opens in the correct location based on the tile grid provided by the Client.	Visual
Conformance of sheet to index grid (Las files to tile scheme polygon)	No gaps between the tiles and matches at grid line at 1:1 view.	Visual

2.4 DATA DENSITY AND DATA VOID CHECK

The data density for this data is expected to be 1 point in 1mX1m grid as the data has been collected with 1m NPS. The data void in the data was checked based on the guidelines given in USGS V13. A regular grid, with cell size equal to the design NPS*2 will be laid over the data. At least 90% of the cells in the grid shall contain at least 1 LiDAR point.

The results on Data Density and Data Void are summarized in Appendix 1.
Both the results are within the specs and the data is accepted.

2.5 CHECK POINT ANALYSIS

The check points collected independently were validated and are provided in Table 9.

Table 9 Analysis of Checkpoint

Check number of FVA points and their distribution	Yes
Check number of SVA points within each class category	Yes
Check the photographs of the all points to the appropriateness	Yes
Check Type, order and stability of the base stations used.	Yes
Check baseline vectors for length (20KM)	Yes
Check adjustment for reliability.	Yes
Check duplicated baseline vectors for 5 cm rule	Yes
Check survey report for completeness	Yes

2.6 FUNDAMENTAL VERTICAL ACCURACY

Fundamental Vertical Accuracy (FVA) is defined as “The value by which vertical accuracy can be equitably assessed and compared among datasets. The FVA is determined with vertical checkpoints located only in open terrain, where there is a very high probability that the sensor will have detected the ground surface.” (FEMA Procedure Memorandum No. 61- Standards for LiDAR and Other High Quality Digital topography, September, 27, 2010, Page 6) The twenty-five (25) points are to be evenly distributed throughout the project area.

The FVA has been computed and the results are given in Table 10.

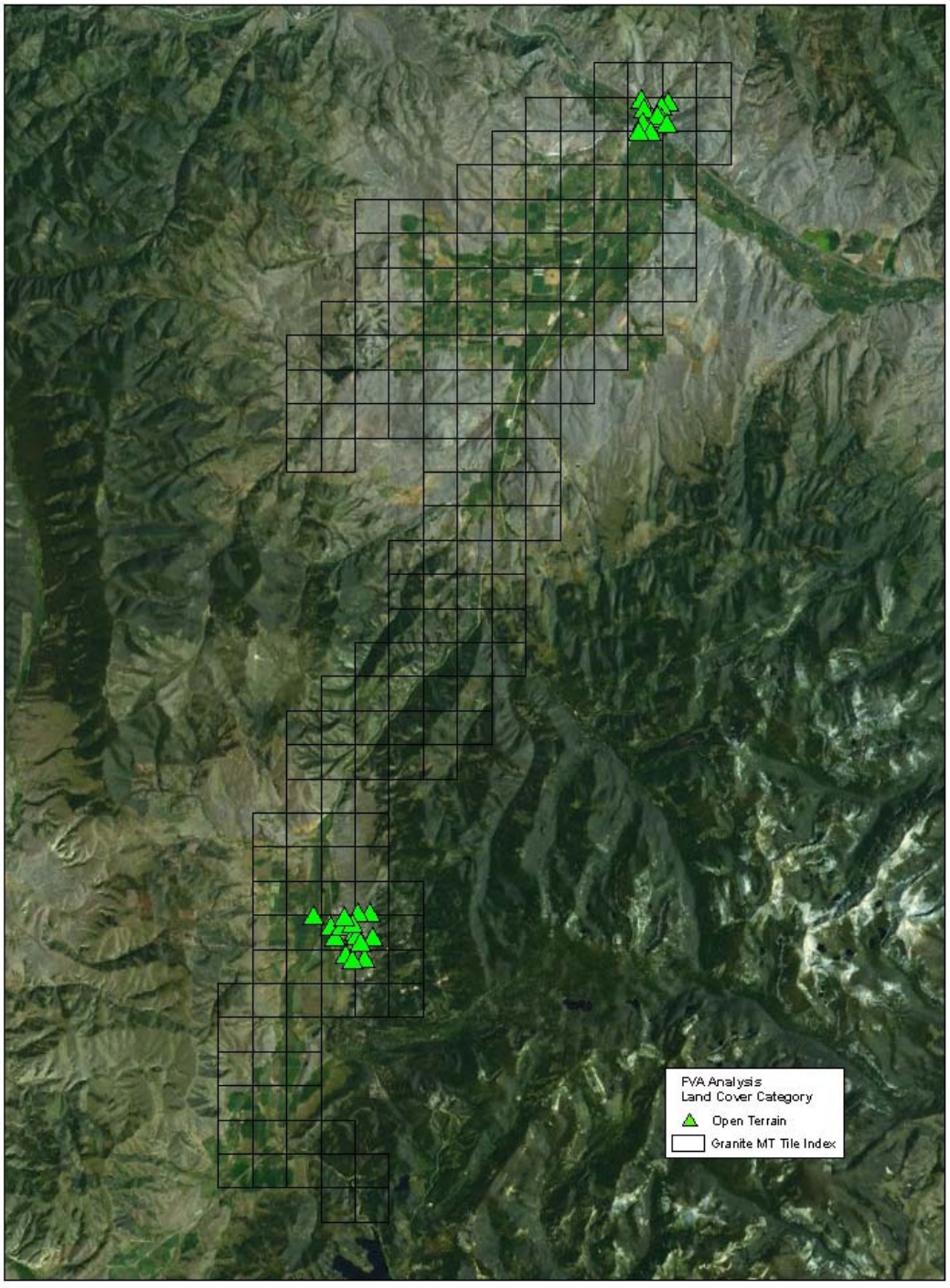


Fig 2: The FVA point's distribution is shown in the above diagram and results are summarized in the following table.

Table 10 Fundamental Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ΔZ²
DRU_FVA1	DRU_FVA1	1056020.823	1056020.823	904320.562	904320.562	4371.450	4371.500	-0.050	0.050
DRU_FVA2	DRU_FVA2	1055059.894	1055059.894	903648.425	903648.425	4156.160	4156.400	-0.240	0.240
DRU_FVA3	DRU_FVA3	1052033.630	1052033.630	904693.253	904693.253	3958.480	3958.510	-0.030	0.030
DRU_FVA4	DRU_FVA4	1052508.186	1052508.186	903382.591	903382.591	3949.110	3949.090	0.020	0.020
DRU_FVA5	DRU_FVA5	1055141.268	1055141.268	901962.214	901962.214	3966.330	3966.390	-0.060	0.060
DRU_FVA6	DRU_FVA6	1054381.687	1054381.687	902413.391	902413.391	3962.780	3962.860	-0.080	0.080
DRU_FVA7	DRU_FVA7	1055859.154	1055859.154	901237.589	901237.589	3979.660	3979.570	0.090	0.090
DRU_FVA8	DRU_FVA8	1052219.813	1052219.813	901428.585	901428.585	3951.720	3951.780	-0.060	0.060
DRU_FVA9	DRU_FVA9	1053522.227	1053522.227	899930.045	899930.045	3952.810	3952.750	0.060	0.060
DRU_FVA10	DRU_FVA10	1051802.341	1051802.341	899936.414	899936.414	3956.000	3956.040	-0.040	0.040
PHI_FVA1	PHI_FVA1	1004043.246	1004043.246	784954.847	784954.847	5100.230	5100.110	0.120	0.120
PHI_FVA2	PHI_FVA2	1006625.148	1006625.148	783449.527	783449.527	5133.330	5133.290	0.040	0.040
PHI_FVA3	PHI_FVA3	1007129.836	1007129.836	781904.882	781904.882	5166.330	5166.500	-0.170	0.170
PHI_FVA4	PHI_FVA4	1008864.251	1008864.251	779428.696	779428.696	5229.930	5229.780	0.150	0.150
PHI_FVA5	PHI_FVA5	1012698.170	1012698.170	781889.217	781889.217	5336.930	5336.960	-0.030	0.030
PHI_FVA6	PHI_FVA6	1011558.895	1011558.895	778715.470	778715.470	5359.570	5359.410	0.160	0.160
PHI_FVA7	PHI_FVA7	1009735.936	1009735.936	778610.689	778610.689	5240.000	5239.900	0.100	0.100
PHI_FVA8	PHI_FVA8	1012266.592	1012266.592	785368.415	785368.415	5485.810	5485.910	-0.100	0.100
PHI_FVA9	PHI_FVA9	1010643.336	1010643.336	785515.413	785515.413	5340.830	5340.640	0.190	0.190
PHI_FVA10	PHI_FVA10	1008171.320	1008171.320	783524.551	783524.551	5160.180	5160.120	0.060	0.060
PHI_FVA11	PHI_FVA11	1010170.300	1010170.300	782601.785	782601.785	5229.360	5229.310	0.050	0.050
PHI_FVA12	PHI_FVA12	1010407.593	1010407.593	782081.081	782081.081	5227.050	5226.940	0.110	0.110
PHI_FVA13	PHI_FVA13	1011059.308	1011059.308	781181.416	781181.416	5308.650	5308.330	0.320	0.320
PHI_FVA14	PHI_FVA14	1009823.981	1009823.981	783954.911	783954.911	5258.740	5258.800	-0.060	0.060
PHI_FVA15	PHI_FVA15	1008628.030	1008628.030	784754.657	784754.657	5215.300	5215.280	0.020	0.020
								Sum	1.688
								Average	0.060
								RMSEr	0.246
								FVA (ft)	0.236
								FVA (cm)	7.198

Granite 2-ft area tested 0.236 ft (7.198 centimeters) Fundamental Vertical Accuracy at 95% confidence level in open terrain using RMSEz x 1.9600. The Granite 2-ft area FVA value passes the minimum requirement of 24.5 centimeters. The table above describes the points and statistics associated with the FVA testing.

3. MILESTONE 2 – LIDAR DATA QA/QC FOR PROCESSED AREA

Milestone 2 review consists of a quantitative analysis of the supplemental and consolidated vertical accuracy as well as a qualitative review of classified bare earth LiDAR and breaklines. Supplemental and consolidated vertical accuracies are checked by comparing the elevation differences from surveyed points in a variety of land cover categories to the bare earth TIN surface created from the classified LiDAR. Qualitative review of the LiDAR is a visual inspection of the data for voids or gaps, noise, artifacts, aggressive filtering, continuity between swaths, breakline connectivity, monotonicity, topology, etc.

3.1 QUANTITATIVE ANALYSIS

Supplemental Vertical Accuracy (SVA) is the result of a test of accuracy of z-values over areas with ground cover categories or combination of categories other than open terrain. Each land cover type representing 10% or more of the total project area was tested and reported as an SVA.

The SVA has been computed and the results are given in Table 11.

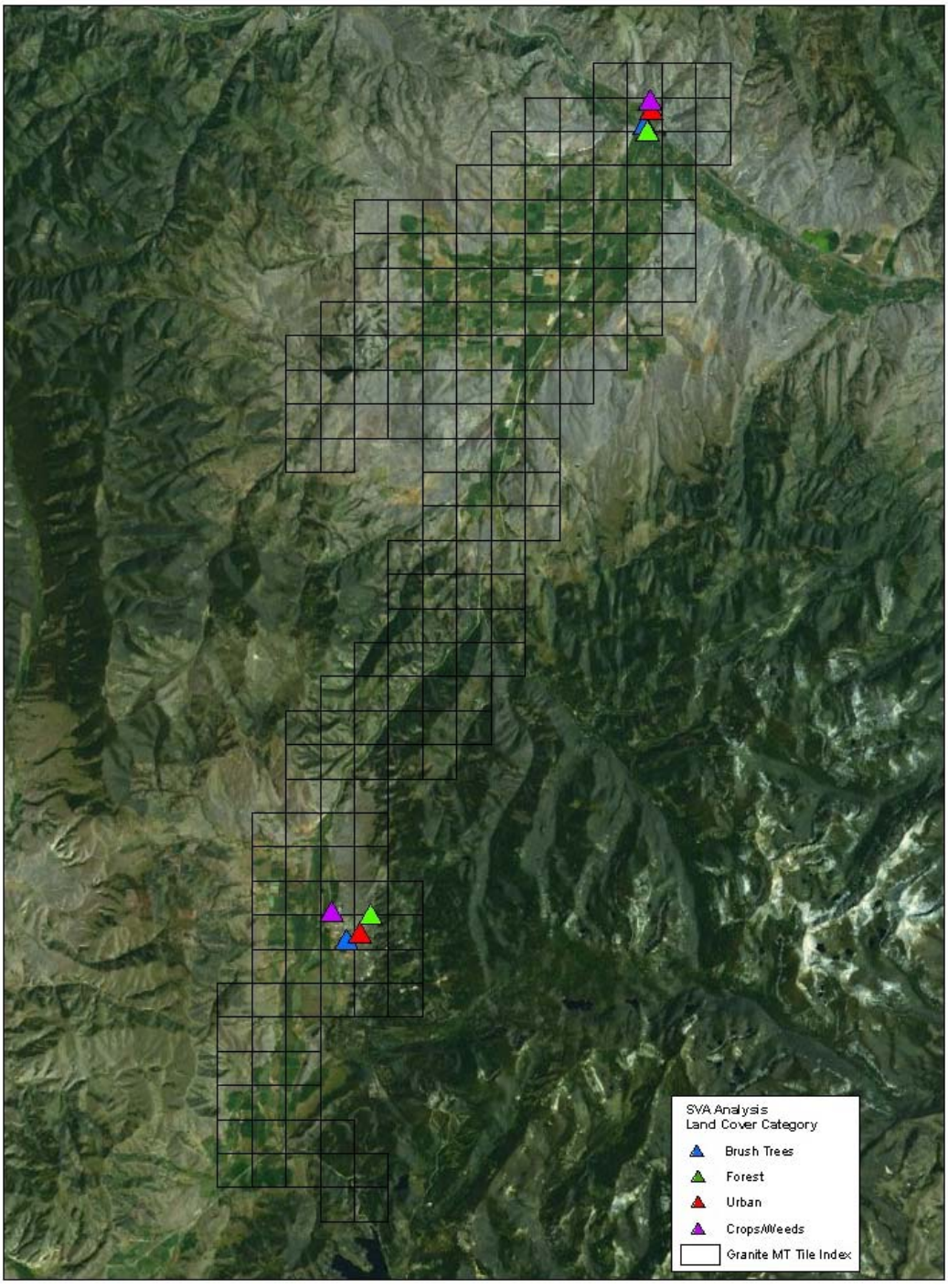


Fig 3: The SVA points' distribution is shown in the above diagram and results are summarized in the following table.

Table 11 Supplemental Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ABS ΔZ
DRU_SVABT1	DRU_SVABT1	1052736.596	1052736.596	901004.149	901004.149	3946.550	3946.955	-0.405	0.405
DRU_SVAF1	DRU_SVAF1	1053017.175	1053017.175	900039.454	900039.454	3950.940	3950.905	0.035	0.035
DRU_SVAU1	DRU_SVAU1	1053666.801	1053666.801	903158.29	903158.29	3974.370	3974.162	0.208	0.208
DRU_SVAWC1	DRU_SVAWC1	1053517.847	1053517.847	904507.711	904507.711	4159.800	4159.724	0.076	0.076
PHI_SVABT1	PHI_SVABT1	1009012.886	1009012.886	781256.741	781256.741	5225.990	5226.374	-0.384	0.384
PHI_SVAF1	PHI_SVAF1	1012620.142	1012620.142	785067.692	785067.692	5509.670	5509.525	0.145	0.145
PHI_SVAU1	PHI_SVAU1	1010948.426	1010948.426	782371.314	782371.314	5244.080	5243.980	0.100	0.100
PHI_SVAWC1	PHI_SVAWC1	1006852.577	1006852.577	785410.916	785410.916	5121.290	5121.058	0.232	0.232
DRU_SVABT1	DRU_SVABT1	1052736.596	1052736.596	901004.149	901004.149	3946.550	3946.955	-0.405	0.405
DRU_SVAF1	DRU_SVAF1	1053017.175	1053017.175	900039.454	900039.454	3950.940	3950.905	0.035	0.035
DRU_SVAU1	DRU_SVAU1	1053666.801	1053666.801	903158.29	903158.29	3974.370	3974.162	0.208	0.208
DRU_SVAWC1	DRU_SVAWC1	1053517.847	1053517.847	904507.711	904507.711	4159.800	4159.724	0.076	0.076
PHI_SVABT1	PHI_SVABT1	1009012.886	1009012.886	781256.741	781256.741	5225.990	5226.374	-0.384	0.384
PHI_SVAF1	PHI_SVAF1	1012620.142	1012620.142	785067.692	785067.692	5509.670	5509.525	0.145	0.145
PHI_SVAU1	PHI_SVAU1	1010948.426	1010948.426	782371.314	782371.314	5244.080	5243.980	0.100	0.100
PHI_SVAWC1	PHI_SVAWC1	1006852.577	1006852.577	785410.916	785410.916	5121.290	5121.058	0.232	0.232
								SVA (ft)	**0.405**
								SVA (cm)	**12.351**

Granite 2-ft Area tested 0.405 ft (12.351 centimeters) supplemental vertical accuracy at 95th percentile in urban areas and brush lands and low trees. The Granite SVA value passes the minimum requirement of 36.3 centimeters. The table above describes the points and statistics associated with the SVA testing.

Consolidated Vertical Accuracy (CVA) is the result of a test of accuracy z-values consolidated for two or more of the major land cover categories, representing both open terrain and other land cover categories.

The CVA has been computed and the results are given in Table 12.

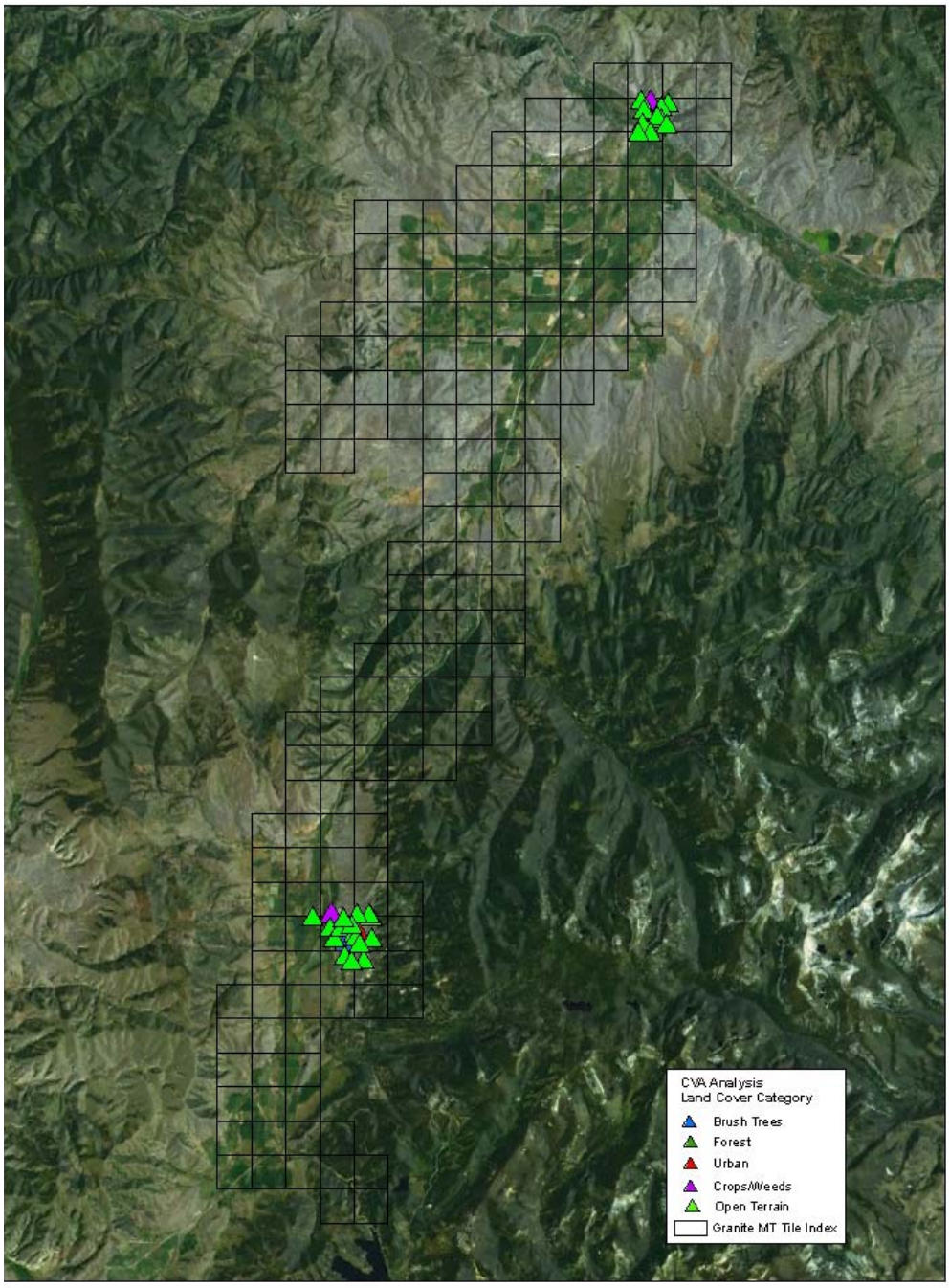


Fig 4: The CVA points' distribution is shown in the above diagram and results are summarized in the following table.

Table 12 Consolidated Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ABS ΔZ
DRU_FVA1	DRU_FVA1	1056020.823	1056020.823	904320.562	904320.562	4371.450	4371.500	-0.050	0.050
DRU_FVA2	DRU_FVA2	1055059.894	1055059.894	903648.425	903648.425	4156.160	4156.400	-0.240	0.240
DRU_FVA3	DRU_FVA3	1052033.630	1052033.630	904693.253	904693.253	3958.480	3958.510	-0.030	0.030
DRU_FVA4	DRU_FVA4	1052508.186	1052508.186	903382.591	903382.591	3949.110	3949.090	0.020	0.020
DRU_FVA5	DRU_FVA5	1055141.268	1055141.268	901962.214	901962.214	3966.330	3966.390	-0.060	0.060
DRU_FVA6	DRU_FVA6	1054381.687	1054381.687	902413.391	902413.391	3962.780	3962.860	-0.080	0.080
DRU_FVA7	DRU_FVA7	1055859.154	1055859.154	901237.589	901237.589	3979.660	3979.570	0.090	0.090
DRU_FVA8	DRU_FVA8	1052219.813	1052219.813	901428.585	901428.585	3951.720	3951.780	-0.060	0.060
DRU_FVA9	DRU_FVA9	1053522.227	1053522.227	899930.045	899930.045	3952.810	3952.750	0.060	0.060
DRU_FVA10	DRU_FVA10	1051802.341	1051802.341	899936.414	899936.414	3956.000	3956.040	-0.040	0.040
PHI_FVA1	PHI_FVA1	1004043.246	1004043.246	784954.847	784954.847	5100.230	5100.110	0.120	0.120
PHI_FVA2	PHI_FVA2	1006625.148	1006625.148	783449.527	783449.527	5133.330	5133.290	0.040	0.040
PHI_FVA3	PHI_FVA3	1007129.836	1007129.836	781904.882	781904.882	5166.330	5166.500	-0.170	0.170
PHI_FVA4	PHI_FVA4	1008864.251	1008864.251	779428.696	779428.696	5229.930	5229.780	0.150	0.150
PHI_FVA5	PHI_FVA5	1012698.170	1012698.170	781889.217	781889.217	5336.930	5336.960	-0.030	0.030
PHI_FVA6	PHI_FVA6	1011558.895	1011558.895	778715.470	778715.470	5359.570	5359.410	0.160	0.160
PHI_FVA7	PHI_FVA7	1009735.936	1009735.936	778610.689	778610.689	5240.000	5239.900	0.100	0.100
PHI_FVA8	PHI_FVA8	1012266.592	1012266.592	785368.415	785368.415	5485.810	5485.910	-0.100	0.100
PHI_FVA9	PHI_FVA9	1010643.336	1010643.336	785515.413	785515.413	5340.830	5340.640	0.190	0.190
PHI_FVA10	PHI_FVA10	1008171.320	1008171.320	783524.551	783524.551	5160.180	5160.120	0.060	0.060
PHI_FVA11	PHI_FVA11	1010170.300	1010170.300	782601.785	782601.785	5229.360	5229.310	0.050	0.050
PHI_FVA12	PHI_FVA12	1010407.593	1010407.593	782081.081	782081.081	5227.050	5226.940	0.110	0.110
PHI_FVA13	PHI_FVA13	1011059.308	1011059.308	781181.416	781181.416	5308.650	5308.330	0.320	0.320
PHI_FVA14	PHI_FVA14	1009823.981	1009823.981	783954.911	783954.911	5258.740	5258.800	-0.060	0.060
PHI_FVA15	PHI_FVA15	1008628.030	1008628.030	784754.657	784754.657	5215.300	5215.280	0.020	0.020
DRU_SVABT1	DRU_SVABT1	1052736.596	1052736.596	901004.149	901004.149	3946.550	3946.955	-0.405	0.405
DRU_SVAF1	DRU_SVAF1	1053017.175	1053017.175	900039.454	900039.454	3950.940	3950.905	0.035	0.035
DRU_SVAU1	DRU_SVAU1	1053666.801	1053666.801	903158.29	903158.29	3974.370	3974.162	0.208	0.208
DRU_SVAWC1	DRU_SVAWC1	1053517.847	1053517.847	904507.711	904507.711	4159.800	4159.724	0.076	0.076
PHI_SVABT1	PHI_SVABT1	1009012.886	1009012.886	781256.741	781256.741	5225.990	5226.374	-0.384	0.384
PHI_SVAF1	PHI_SVAF1	1012620.142	1012620.142	785067.692	785067.692	5509.670	5509.525	0.145	0.145
PHI_SVAU1	PHI_SVAU1	1010948.426	1010948.426	782371.314	782371.314	5244.080	5243.980	0.100	0.100
PHI_SVAWC1	PHI_SVAWC1	1006852.577	1006852.577	785410.916	785410.916	5121.290	5121.058	0.232	0.232
DRU_SVABT1	DRU_SVABT1	1052736.596	1052736.596	901004.149	901004.149	3946.550	3946.955	-0.405	0.405

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ABS ΔZ
DRU_SVAF1	DRU_SVAF1	1053017.175	1053017.175	900039.454	900039.454	3950.940	3950.905	0.035	0.035
DRU_SVAU1	DRU_SVAU1	1053666.801	1053666.801	903158.29	903158.29	3974.370	3974.162	0.208	0.208
DRU_SVAWC1	DRU_SVAWC1	1053517.847	1053517.847	904507.711	904507.711	4159.800	4159.724	0.076	0.076
PHI_SVABT1	PHI_SVABT1	1009012.886	1009012.886	781256.741	781256.741	5225.990	5226.374	-0.384	0.384
PHI_SVAF1	PHI_SVAF1	1012620.142	1012620.142	785067.692	785067.692	5509.670	5509.525	0.145	0.145
PHI_SVAU1	PHI_SVAU1	1010948.426	1010948.426	782371.314	782371.314	5244.080	5243.980	0.100	0.100
PHI_SVAWC1	PHI_SVAWC1	1006852.577	1006852.577	785410.916	785410.916	5121.290	5121.058	0.232	0.232
DRU_SVABT1	DRU_SVABT1	1052736.596	1052736.596	901004.149	901004.149	3946.550	3946.955	-0.405	0.405
DRU_SVAF1	DRU_SVAF1	1053017.175	1053017.175	900039.454	900039.454	3950.940	3950.905	0.035	0.035
								CVA (ft)	**0.384**
								CVA (cm)	**11.69**

Granite 2-ft Area tested 0.384 ft (11.694 centimeters) consolidated vertical accuracy at the 95th percentile in open terrain, urban areas, brush lands and low trees. The Granite 2-ft area CVA value passes the minimum requirement of 36.3 centimeters. The table below describes the points and statistics associated with the CVA testing.

3.2 QUALITATIVE ANALYSIS

3.2.1 LiDAR Macro Review

During the macro review, the Pre Flight Operations Plan, the Post Flight Aerial Acquisition and Calibration Report, and the Checklist for Aerial Acquisition Report were reviewed from Milestone 1 and confirmed to be complete and passed.

Table 13 Checklist for Quality Assurance of Terrain Products

CHECKLIST	PASS/FAIL	COMMENTS
Vertical datum correct	**Pass**	
Horizontal datum correct	**Pass**	
Projection correct	**Pass**	
Vertical units correct	**Pass**	
Horizontal units correct	**Pass**	
Each return contains – GPS week, GPS second, easting, northing, elevation, intensity, return # and classification	**Pass**	
No duplicate entries	**Pass**	
GPS second reported to nearest microsecond	**Pass**	
Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	**Pass**	
Classifications correct – 1. Unclassified; 2. Bare-earth ground; 7. Noise; 9. Water; 10. Ignored ground; 11. Withheld	**Pass**	
Deliverable tiles checked for significant gaps not covered by aerial acquisition checks and/or caused by data post-processing/filtering	**Pass**	

The following table highlights the main components of the qualitative analysis as it pertains to the visual inspection of the bare earth LiDAR. For the ground points (bare earth) review, the data were checked for correct classification and cleanliness. No more than 2% of the project area classified to bare ground should contain artifacts such as buildings, trees, overpasses, or other above-ground features in the ground point classification (Class 2). In addition, no more than 2% of the project area shall contain incorrect classification of points. The total classified project area was calculated and the total area of errors was calculated. The total area of errors was compared to the total processed area and the results were less than 2% of the total processed area contained errors.

Table 14 Qualitative Analysis of DTM

LIDAR ACCEPTANCE CATEGORY	DESCRIPTION	PASS/FAIL
Ground Points (Bare Earth)	Post-processed to remove structures and vegetation with <2 % residual artifacts	**Pass** – Error extent less than 2% of the processed tiles extent
Continuity	No gaps of sufficient size. No obvious vertical offsets between adjoining strips	**Pass**
Inconsistent Post Processing/Editing	No visible variations in DTM.	**Pass**
Over-smoothing	Smoothing techniques are not aggressive enough to remove topographic features necessary to define drainage features	**Pass**
Artifacts	No obvious artifacts, spikes, holes, or blunder.	**Pass**
Classification Used	Class 1 = unclassified; Class 2 = ground; Class 7 = Low point/noise Class 9 = Water Class 10 = Ignored Class 11 = Withheld	**Pass**
Low Confidence	2D Polygon shapefile meeting database specifications set forth in PM61_LIDAR Specs.	**Pass**

3.3 Low Confidence Areas

FEMA requires that low confidence areas be delineated by the data provider to indicate areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation even though the specified nominal pulse spacing was met or exceeded in those areas. For the Granite 2-ft Area project area, there was not an area of low confidence noted.

3.4 Breaklines

Submitted breaklines were reviewed through a combination of automated processes along with a visual review. Detailed QC was performed on all breaklines in 7 out of 14 project tiles. Some of the automated review processes were applied to all breaklines. The single drain lines were compared to bare earth profiles to ensure that they fall within water channels. 3D centerlines profiles were checked visually for all breaklines that intersect sample tiles, along with visual line work checks. Breaklines vertices were converted to points and compared to each other's within and across breaklines and surrounding ground values. The breaklines follow a downstream trend with the first upstream vertex being higher than the last downstream vertex. The elevations for each vertex decrease steadily as the stream flows downstream. The following table highlights the main components of the qualitative analysis as it pertains to the visual inspection of the breakline submittal. This qualitative analysis includes verifying completeness, topology, consistency, and location of the breakline features.

Table 15 Breakline Acceptance

Breakline Acceptance Category		Pass/Fail
Check for monotonicity of hydro breaklines.	Visual	**Pass**
Verify that breakline vertices have z values equal to or less than the surrounding ground points.	Automated	**Pass**
Vertices should not have a 0 or null elevation	Automated	**Pass**
Vertices should not have excessive min or max z-values when compared to adjacent vertices	Visual	**Pass**
Double line stream breaklines elevations must match within 2 ft from each side of the stream	Visual	**Pass**
Check the metadata of the Milestone 2 delivery. Should include discussion on each delivered feature and a description of the creation process unique to that feature class. Should comply with FEMA Terrain Metadata Profile.	Visual	**Pass**
Verify ponding water breaklines have constant elevation and are equal to or less than the surrounding ground points.	Visual	**Pass**
Assure breaklines meet all specifications for completeness, size and feature type. Water body breaklines for polygons >2acres, stream centerline breaklines for streams <100' wide and shown on a USGS 7.5min Quads, and edge of water breaklines for streams >100' wide	Visual	**Pass**

BREAKLINE ACCEPTANCE CATEGORY		PASS/FAIL
Stream breaklines should break at culverts, and not break at bridges.	Visual	**Pass**
Run topology checks on all GIS lines and polygons.	Automated	**Pass**
Horizontal placement-stream should align horizontally with the LIDAR data	Visual	**Pass**
Culvert breaklines must snap to stream endpoints on both sides, and have the same elevation as the stream breakline at the snapping location.	Automated	**Pass**
Bridge breaklines should outline the bridge deck	Visual	**N/A**

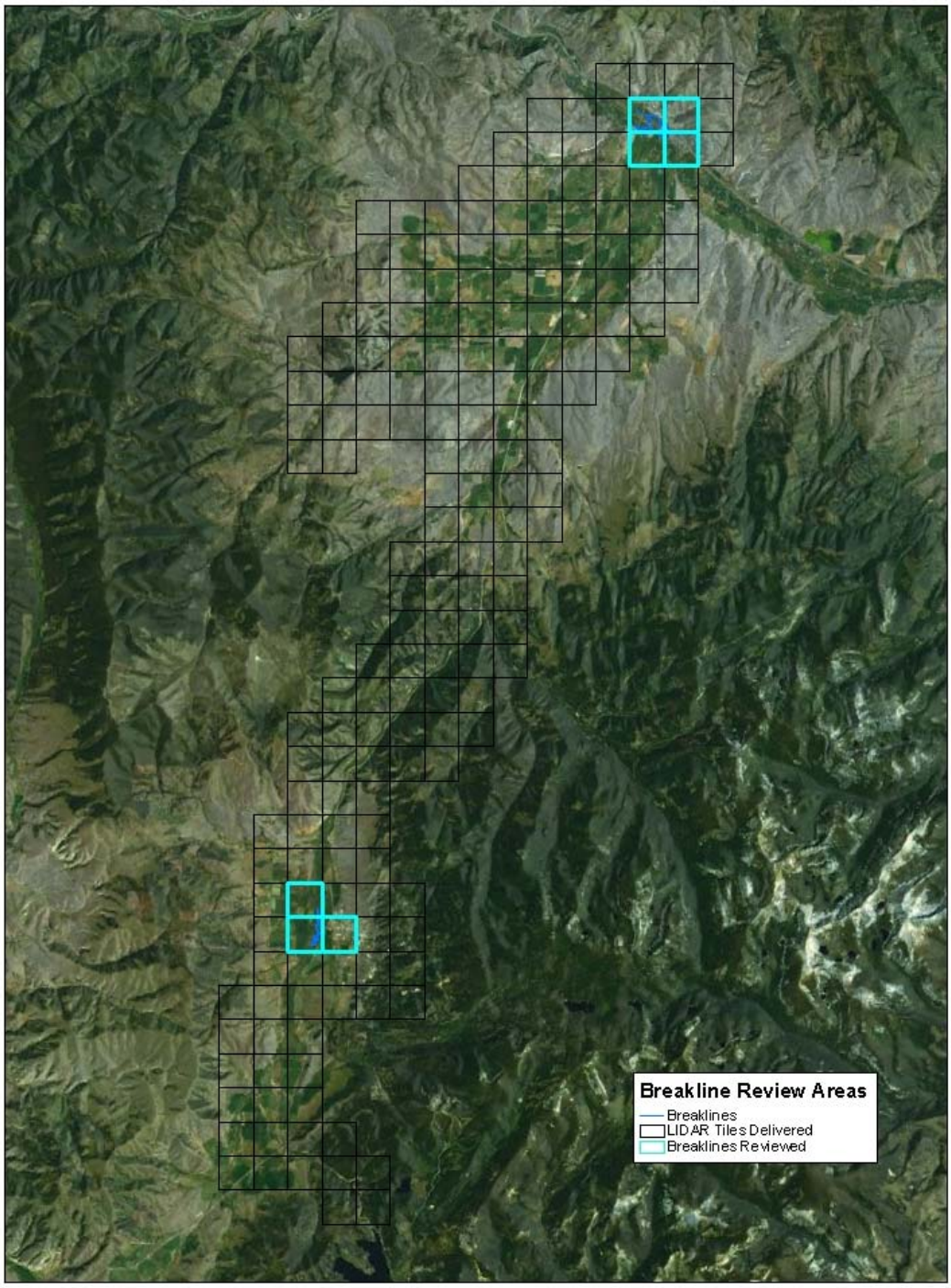


Fig 5. Breakline Review process diagram.

3.5 METADATA

Metadata were visually inspected and confirmed inclusion of documentation on classification methodology, breakline creation, low confidence area minimization, etc.

3.6 List of Deliverables

The major deliverables are provided in Table 16.

Table 16 Major Deliverables

Federal Geographic Data Committee compliant metadata	Metadata file was provided
Reports (Collection, Survey, Processing, and QA/QC reports)	Yes
Raw point cloud in an LAS v 1.2 or 1.3 format	Yes
Classified point cloud in an LAS v 1.2 or 1.3 format	Yes
Break lines (Stream centerlines, drainage ditches, and tops and bottoms of stream banks in an ESRI shape file or geo database format	Yes
Checklist documenting QC processing steps completed	Yes
QC Non-conformance documentation	

4. SUMMARY

The LiDAR data for the Granite 2-ft area, MT collection area meets all the FEMA specifications as given on PM 61 document. The data passes the accuracy assessment test for FVA, CVA and SVA. The final dataset passes all quality control specifications and the dataset has adequate documentation from the collection vendor.

5. REFERENCES

Bellamo, Doug A., Memorandum for Regional Risk Analysis Branch Chiefs, Procedure Memorandum No. 61 – Standards for LiDAR and Other High Quality Digital Topography, September, 2010.

Map Modernization Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying, Federal Emergency Management Agency (FEMA), April 2003, from http://www.fema.gov/plan/prevent/fhm/dl_cgs.shtm

U.S. Geological Survey (USGS), National Geospatial Program, LiDAR Guidelines and Base Specification, vers. 13, Effective Date February 22, 2010;

American Society for Photogrammetry and Remote Sensing (ASPRS), ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, vers. 1.0, May 24, 2004.

Appendix 1 Data Density and Data Void check results

Table 9 Data Density Check

No. of Tiles			14			
No. of LAS Tiles			14			
NPS			1 Meter			
Tile Name	**No. of Points**	**Z Min (feet)**	**Z Max (feet)**	**Z Mean (feet)**	**Point Density / Sq m**	**Comment**
Drummond_2ft_01	24690942	3717.61	5619.39		10.6308	
Drummond_2ft_02	24814365	4061.92	4917.8		10.68394	
Drummond_2ft_03	24957449	3708.73	5610.14		10.74555	
Drummond_2ft_04	26419698	3936.32	4556.24		11.37512	
Drummond_2ft_05	12720419	3878.78	5032.2		5.476836	
Drummond_2ft_06	23419230	3916.4	4642.25		10.08326	
Philipsburg_2ft_01	25725132	5025.53	6283.36		11.07608	
Philipsburg_2ft_02	25076123	5032.21	5333.9		10.79664	
Philipsburg_2ft_03	28469211	5273.73	6178.39		12.25755	
Philipsburg_2ft_04	26297972	5082.51	5663.38		11.32272	
Philipsburg_2ft_05	25856037	4911.94	6816.05		11.13244	
Philipsburg_2ft_06	28103014	5015.95	6945.09		12.09988	
Philipsburg_2ft_07	25241865	5147.32	5388.38		10.868	
Philipsburg_2ft_08	27328517	5240.97	5973.82		11.76642	

Table 10 Check for Data Void

Tile Size	5000x5000 Feet
Grid Size	2 Meters
Pass Percent	90

LASFILE	NO OF POINTS	NO OF GRIDS/TILE	NO OF GRIDS MEETING THE SPEC	PERCENT OF GRIDS MEETING THE SPEC	STATUS
Drummond_2ft_01	24552086	582169	580801	99.76501669	Pass
Drummond_2ft_02	24606633	582169	581267	99.84506217	Pass
Drummond_2ft_03	24377586	582169	580988	99.79713794	Pass
Drummond_2ft_04	26272126	582169	581386	99.86550297	Pass
Drummond_2ft_05	12452950	582169	579845	99.6008032	Pass
Drummond_2ft_06	23104112	582169	572203	98.28812596	Pass
Philipsburg_2ft_01	25712212	582169	580816	99.76759326	Pass
Philipsburg_2ft_02	25053297	582169	572443	98.3293511	Pass
Philipsburg_2ft_03	27332231	582169	582164	99.99914114	Pass
Philipsburg_2ft_04	26291395	582169	581830	99.94176949	Pass
Philipsburg_2ft_05	25755457	582169	582146	99.99604926	Pass
Philipsburg_2ft_06	26396281	582169	582117	99.99106789	Pass
Philipsburg_2ft_07	25208809	582169	581406	99.8689384	Pass
Philipsburg_2ft_08	25710614	582169	579847	99.60114675	Pass

The tiles that were failed were visually checked and it was observed that the issue is due to water bodies present (as LiDAR is absorbed and not reflected) and it is acceptable. The data void check is pass 100%.