

# LiDAR Independent QA/QC Report: Goshen County, Wyoming

Contract #HSFE60-15-D-0003, Task Order #HSFE08-16-J-0216

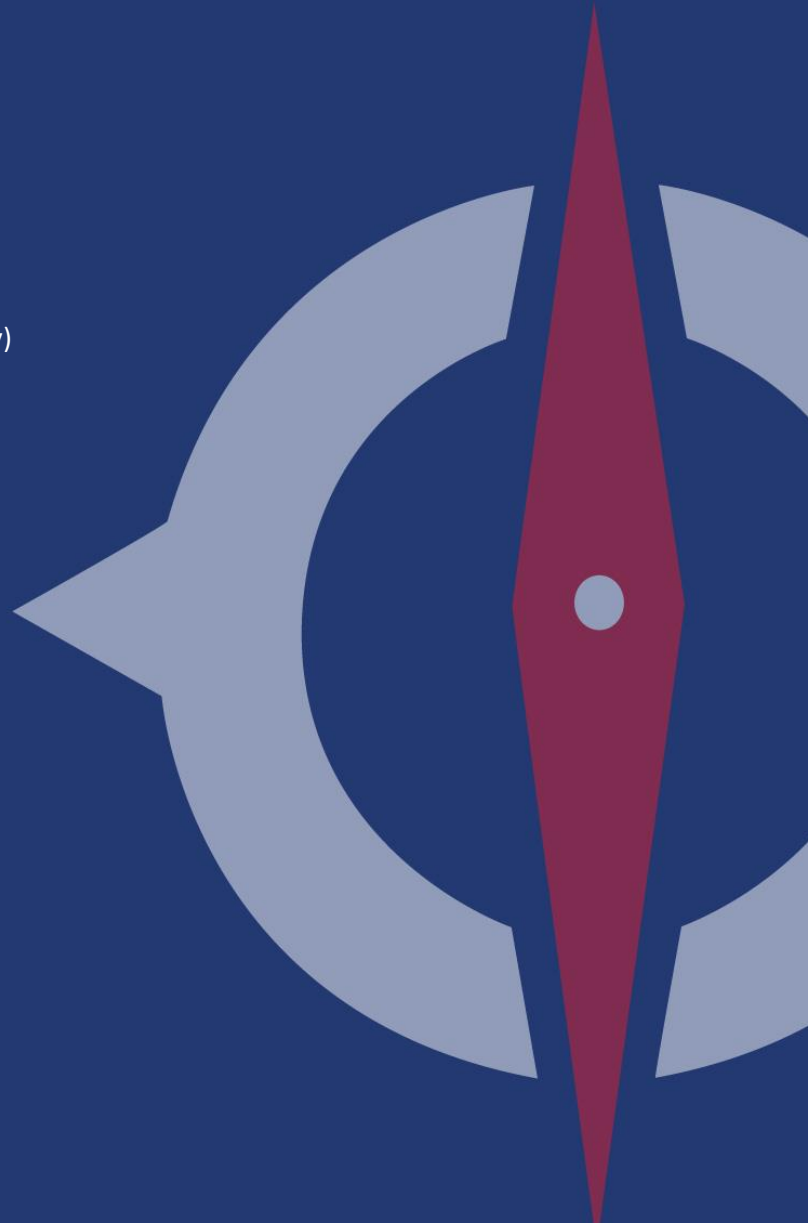
August 31, 2017

**Prepared for:**

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## DOCUMENT HISTORY

### REVISION HISTORY

Version Number	Version Date	Summary Changes	Team/Author
1.0	August 31, 2017	Goshen County, WY LiDAR Independent QA/QC Report	Bobby Riley

### APPROVALS

This document requires the approval of the following persons:

Role	Name	Phone Extension	Title (CLIN/RMC)	Review Date	Approved Date
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**Subject: Goshen County, Wyoming LiDAR Collection, Contract # HSFE60-15-D-0003, Task Order HSFE08-16-J-0216**

Dear Mr. Zuzak and Ms. Brabenec,

The Compass PTS JV is pleased to provide the Goshen County, Wyoming LiDAR Independent QA/QC Report developed as part of this task order. The Goshen County LiDAR collection, as specified in the scope of work and required by FEMA Standards for Flood Risk Analysis and Mapping, was designed, collected, and processed in accordance with the United States Geological Survey-National Geospatial Program's LiDAR Base Specification Version 1.2 (November 2014). The following table summarizes the key components to a Quality Level 2 (QL2) collection as required by the USGS specifications and the independently assessed actual results.

Test	Design	Independent QA/QC Result	Pass/Fail
Nominal Pulse Spacing (m)	≤ 0.71	0.66	Pass
Nominal Pulse Density (pls/m <sup>2</sup> )	≥ 2.0	2.29	Pass
Spatial Distribution and Regularity (% passing)	≥ 90.0	99.5	Pass
Interswath Overlap Consistency (cm)	≤ 8.0	3.81	Pass
NVA (95%) - Raw Point Cloud (cm)	≤ 19.6	6.08	Pass
VVA (95%) - Classified Point Cloud (cm)	≤ 29.4	8.35	Pass
NVA (95%) - Hydroflattened DEM (cm)	≤ 19.6	6.35	Pass
VVA (95%) - Hydroflattened DEM (cm)	≤ 29.4	8.32	Pass

All products referenced herein and included with the Goshen County, Wyoming LiDAR collection deliverable package have been developed to meet or exceed the government's requirements for this task order.

Respectfully submitted,



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## 01 Introduction

As part of the Goshen County, WY LiDAR collection and processing task order (#HSFE09-16-J-0216), Compass has performed independent QA/QC on the collected LiDAR and derivative products. Results of independent QA/QC assessments are presented in this report.

The following guidance and standards documents were considered as part of this independent QA/QC activity:

- FEMA Standards for Flood Risk Analysis and Mapping (Nov 2016)
- United States Geological Survey-National Geospatial Program (USGS-NGP) LiDAR Base Specification Version 1.2 (Nov 2014)
- FEMA Guidance: Elevation (May 2016)
- FEMA Procedure Memorandum (PM) 61: Standards for Lidar and Other High Quality Digital Topography (Sept 2010)

### 1.1 Scope of Work

The Goshen County, Wyoming LiDAR collection was designed in accordance with FEMA and USGS-NGP specifications for Quality Level 2 (QL2), which require the following fundamental criteria be met:

Nominal Pulse Spacing	$\leq 0.71$ meters
Nominal Pulse Density	$\geq 2.0$ pulses per square meter
Nonvegetated Vertical Accuracy (95% confidence)	$\leq 19.6$ centimeters
Vegetated Vertical Accuracy (95 <sup>th</sup> percentile)	$\leq 29.4$ centimeters



## 1.2 Project Site

Goshen County, Wyoming represents the collection's defined project area (DPA) of 2232.16 square miles. With a 100-meter buffer, the buffered project area (BPA) is 2244.95 square miles. All collected and developed data have been assured to extend to the BPA.

Figure 1 depicts the Goshen County Wyoming project site.

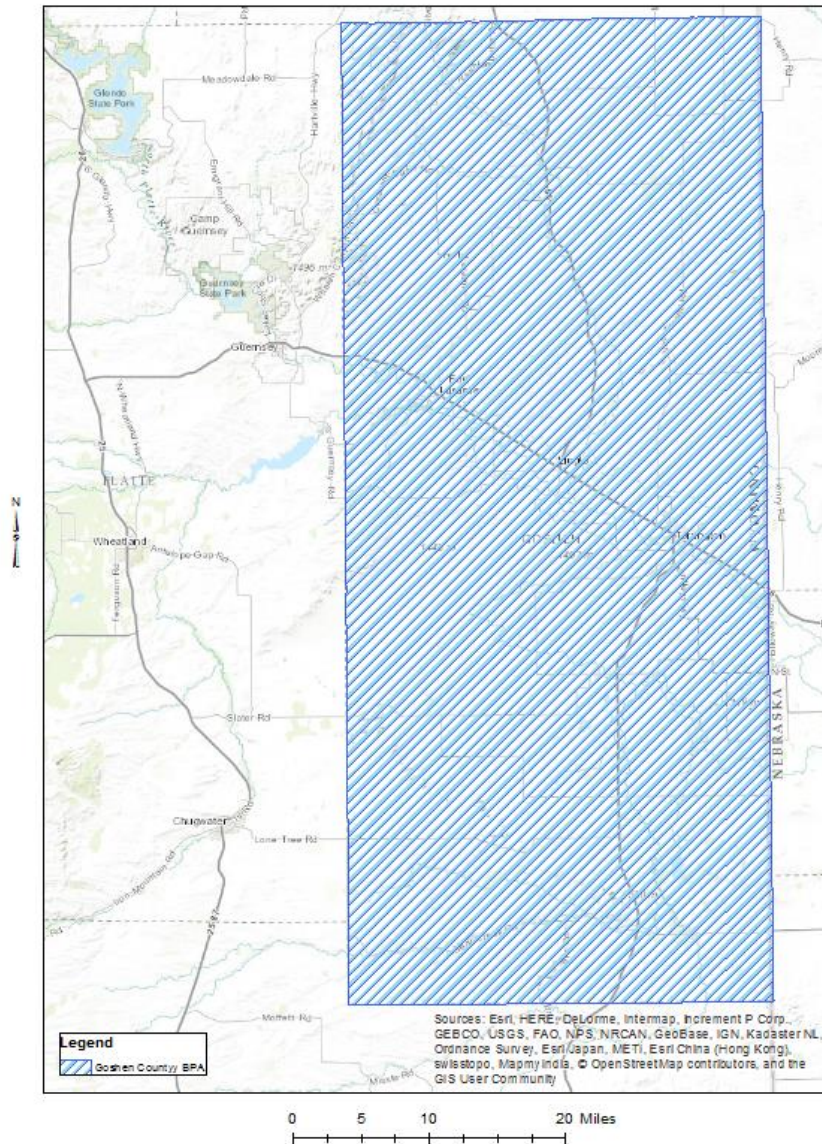


Figure 1: Goshen County Buffered Project Area



### 1.3 Surveyed QC Checkpoints

Two hundred and twenty-three (223) checkpoints were surveyed in support of the Goshen County, Wyoming LiDAR collection. Sixty-nine (69) QC checkpoints were surveyed in open terrain areas and were used to assess the non-vegetated vertical accuracy (NVA) of the raw LiDAR point cloud and hydro-flattened digital elevation model (DEM). Quantity of vegetative vertical accuracy (VVA) check points and vegetation cover represented is summarized in the table below.

<b>Vegetative Cover</b>	<b># Check Points</b>
Low grass	71
High grass	42
Medium grass	7
Sagebrush	2
Scrub brush	1
Low brush	6
Corn	3
Corn (High)	1
Corn (Low)	1
Corn/Sunflowers	1
Brush	12
Trees	6

Figure 2 depicts the QC checkpoints surveyed as part of the Goshen County, Wyoming LiDAR collection task order.

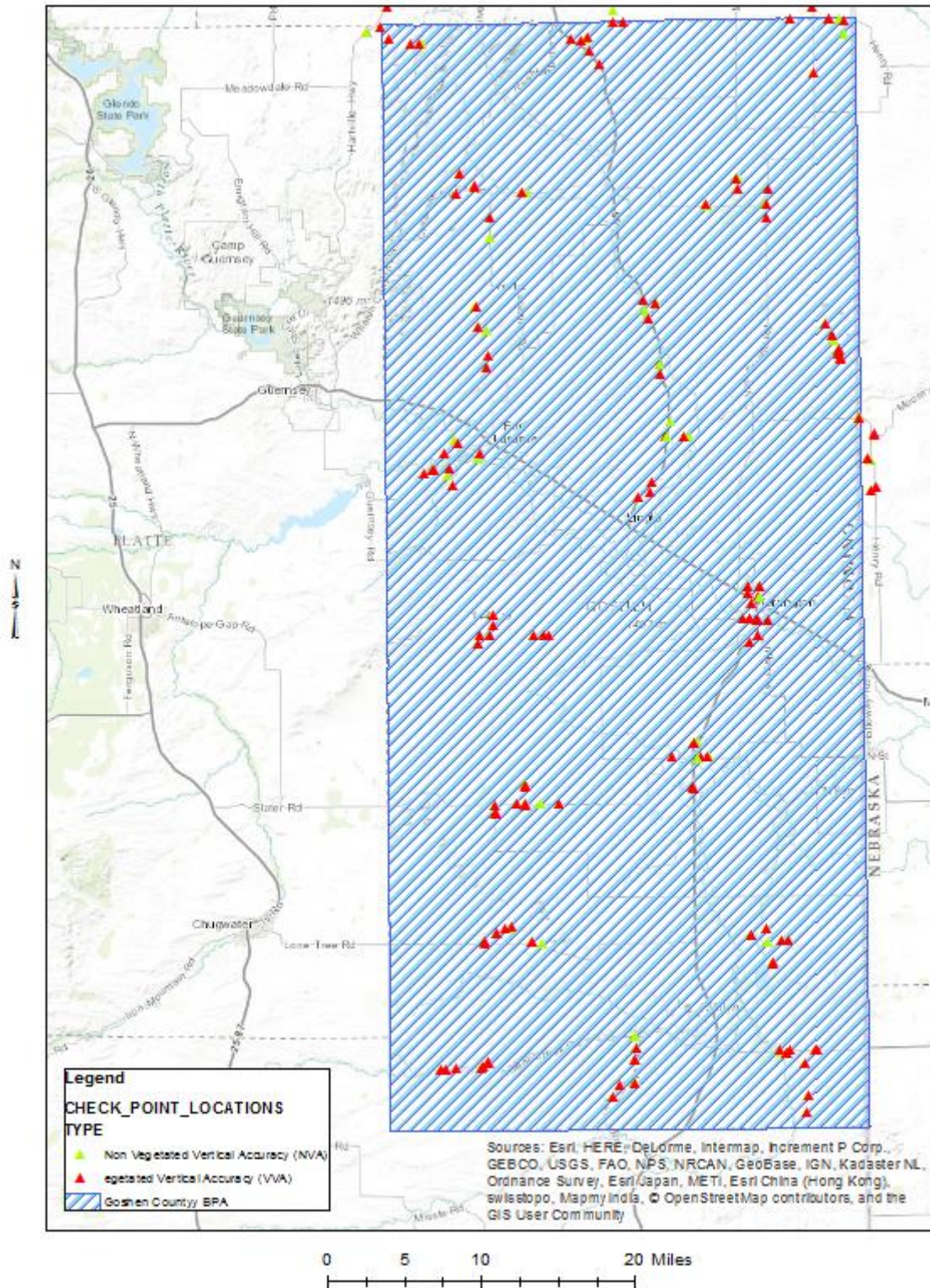


Figure 2: Survey Points





## 02 Independent QA/QC

Independent QA/QC activities were executed against the Goshen County, Wyoming LiDAR collection using a macro and micro review methodology specified in FEMA's PM 61 guidance document. Macro reviews were automated processes and checks to establish overall data quality, completeness, and alignment with project standards and specifications such as horizontal and vertical reference systems and units. Micro reviews were more manual in nature and were used to check 100% of the project area to assure classification and elevation data are representative in the classified LiDAR and derivative products.

### 2.1 Raw LiDAR Point Cloud

The fully calibrated, georeferenced, and adjusted to ground raw LiDAR point cloud was assessed prior to classification and derivative product generation. The nominal pulse spacing (NPS), spatial distribution and regularity, nonvegetated vertical accuracy, and overlap consistency were reviewed.

#### 2.1.1 Nonvegetated Vertical Accuracy

Nonvegetated Vertical Accuracy (NVA) is a fundamental accuracy assessment of any LiDAR collection. The assessment is performed by comparing the elevation values from independently surveyed open terrain QC checkpoints to the TIN and/or DEM surface for the same coordinates. This assessment provides assurance the collection, boresight, and control have been appropriately calibrated to the ground. NVA for the Goshen County, Wyoming LiDAR collection was assessed using the raw point cloud by building a Triangular Irregular Network (TIN) for all pulses around the 69 open terrain QC checkpoints (Note, 3 check points were found to not have adequate LiDAR points around them). Since the checkpoints were surveyed in open terrain, the LiDAR pulses used to construct the TIN had a high probability of representing the ground without interference from structures or vegetation in these areas.

The Root Mean Square Error (RMSE) was calculated at 0.031 meters. The 95% Confidence metric (vertical accuracy RMSE \* 1.96) was calculated at 0.0608 meters, which is well within the FEMA and USGS-NGP requirements of 0.196 meters.

#### 2.1.2 Nominal Pulse Spacing and Density

Across 152 swaths, a total of 13,981,575,208 first return points were identified across 65,834,569,258.72 ft<sup>2</sup> of assessment area to calculate a 0.66 meters Nominal Point Spacing (NPS) and 2.29 points per square meter Nominal Point Density (NPD), which are within tolerance of the USGS-NGP requirements of a NPS less than or equal to 0.71 meters and a NPD greater than or equal to 2 points per square meter.

#### 2.1.3 Spatial Distribution and Regularity

Spatial distribution and regularity of the raw LiDAR point cloud is assessed to ensure the geometrically usable points will approach a uniform and regular lattice rather than a collection of widely spaced, high-density profiles of the terrain. The assessment requires a density grid developed from the swath-based raw point cloud with grid cell sizes equal to twice the design ANPS, or  $2 * 0.7\text{m} = 1.4$  meter resolution grid. Spatial distribution and regularity grids were developed for each swath where the cell values were calculated based on the number of first return pulses counted for each cell area. Across all 152 swaths covering 65,834,569,258.72 ft<sup>2</sup>, 2,926,660,593 pixels having dimension of  $2 \times \text{ANPS}$  (4.6 ft<sup>2</sup>) were



determined to contain at least one first return pulse, resulting in a 99.5% incidence rate, which exceeds the minimum requirement of 90% from the USGS-NGP specifications.

#### 2.1.4 Overlap Consistency

Interswath overlap consistency is a measure of geometric alignment of two overlapping swaths and is the fundamental measure of quality of the calibration or boresight adjustment of the data from each lift and between swaths from a single lift. For this assessment, the overlap data were evaluated using 57,472 point locations within the swath overlap areas (1,641 points exceeded  $\pm 16$ cm, each of which were reviewed and excused based on location (outside overlap area) and surface characteristics (not bare earth or steep slope). The differences between swaths were compared and the RMSE was calculated to 0.038 m with a maximum difference of  $\pm 0.159$  centimeters. These results are within the USGS-NGP requirement of less than or equal to 0.088 m RMSE and  $\pm 0.16$  m for maximum difference.

## 2.2 Classified LiDAR Point Cloud

A 100% micro review of the classified LiDAR point cloud was performed.

Micro review assessment ensured the following classification was used in the LAS 1.4 files:

- Class 1 – Process, but Unclassified
- Class 2 – Bare Earth
- Class 7 – Low Noise
- Class 9 – Water
- Class 10 – Ignored Ground Points (near a breakline)
- Class 17 – Bridge Decks
- Class 18 – High Noise

### 2.2.1 LAS Classification Error

USGS-NGP has a requirement that no more than 1% of the nonwithheld points will have demonstrable errors. To assess the classification error, a bare earth DEM was built using the ground points from the classified LAS files. A 3 foot resolution DEM and a hillshade was created. During visual inspection of the hillshade imagery less than 1% of the classified points were determined to be incorrectly classified. In addition, each point classification was subsampled and reviewed to assess the consistency of the point classification across the entire project area. No anomalous classification patterns were detected.

### 2.2.2 Vegetated Vertical Accuracy

Vegetated Vertical Accuracy (VVA) of the classified LiDAR point cloud was calculated in a similar method as the NVA was calculated on the raw LiDAR point cloud. TINs were developed using the Class 2 – Bare Earth points for areas where vegetated QC checkpoints were surveyed. The TIN elevation value for the QC checkpoint locations was compared to the vegetated QC checkpoints' elevation value. An absolute value difference was applied and the 95th percentile value was calculated. The VVA of the classified LiDAR point cloud was calculated to be 0.084 m, within the maximum threshold of 0.294 cm specified in the USGS-NGP specifications.



## 2.3 Hydro Breaklines

Hydro-flattening breaklines were assessed as part of the Goshen County, Wyoming LiDAR collection independent QA/QC activities. The following bullets were part of the breakline assessment with all features passing QC:

- Water bodies represented by a single elevation value
- Streams and Rivers with bank lines have been respectively flattened
- Breakline features have monotonicity enforced
- Breakline features at or below surrounding terrain
- FEMA standard topology rules have been enforced

## 2.4 Hydro-Flattened DEM

The hydro-flattened DEM micro review tiles were visually inspected to assure the hydro-flattening breaklines were appropriately applied.

- Water bodies were inspected to assure the single value elevation from the breakline flattened the waterbody with the corresponding elevation value.
- Larger stream and river features with bank lines were appropriately flattened with a decreasing gradient as the flow proceed downhill
- DEM flattened areas were lower than the surrounding terrain

### 2.4.1 Nonvegetated Vertical Accuracy

NVA of the hydro-flattened DEM product was assessed using the open terrain QC checkpoints. The hydro-flattened DEM elevation values were compared to the surveyed open terrain QC checkpoint elevation values at the same coordinates. The RMSE was calculated at 0.032 meters. The 95% Confidence metric (vertical accuracy RMSE \* 1.96) was calculated at 0.063 meters, which is well within the FEMA and USGS-NGP requirements of 0.196 meters.

### 2.4.2 Vegetated Vertical Accuracy

VVA of the hydro-flattened DEM product was assessed using the vegetated QC checkpoints. The hydro-flattened DEM elevation values were compared to the surveyed vegetated QC checkpoint elevation values at the same coordinates. An absolute value difference was applied and the 95th percentile value was calculated. The VVA of the hydro-flattened DEM was calculated to be 0.083 m, within the maximum threshold of 29.4 cm specified in the USGS-NGP specifications.



### 03 Conclusions

The independent QA/QC of the Goshen County, Wyoming LiDAR collection assures all deliverable products adhere to the collection's scope of work, FEMA's Standards for Flood Risk Analysis and Mapping, and the USGS-NGP LiDAR Base Specifications Version 1.2 for QL2 LiDAR.

The following summary table provides the fundamental QA/QC requirements and associated actual results.

Test	Design	Independent QA/QC Result	Pass/Fail
Nominal Pulse Spacing (m)	≤ 0.71	0.66	Pass
Nominal Pulse Density (pls/m <sup>2</sup> )	≥ 2.0	2.29	Pass
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