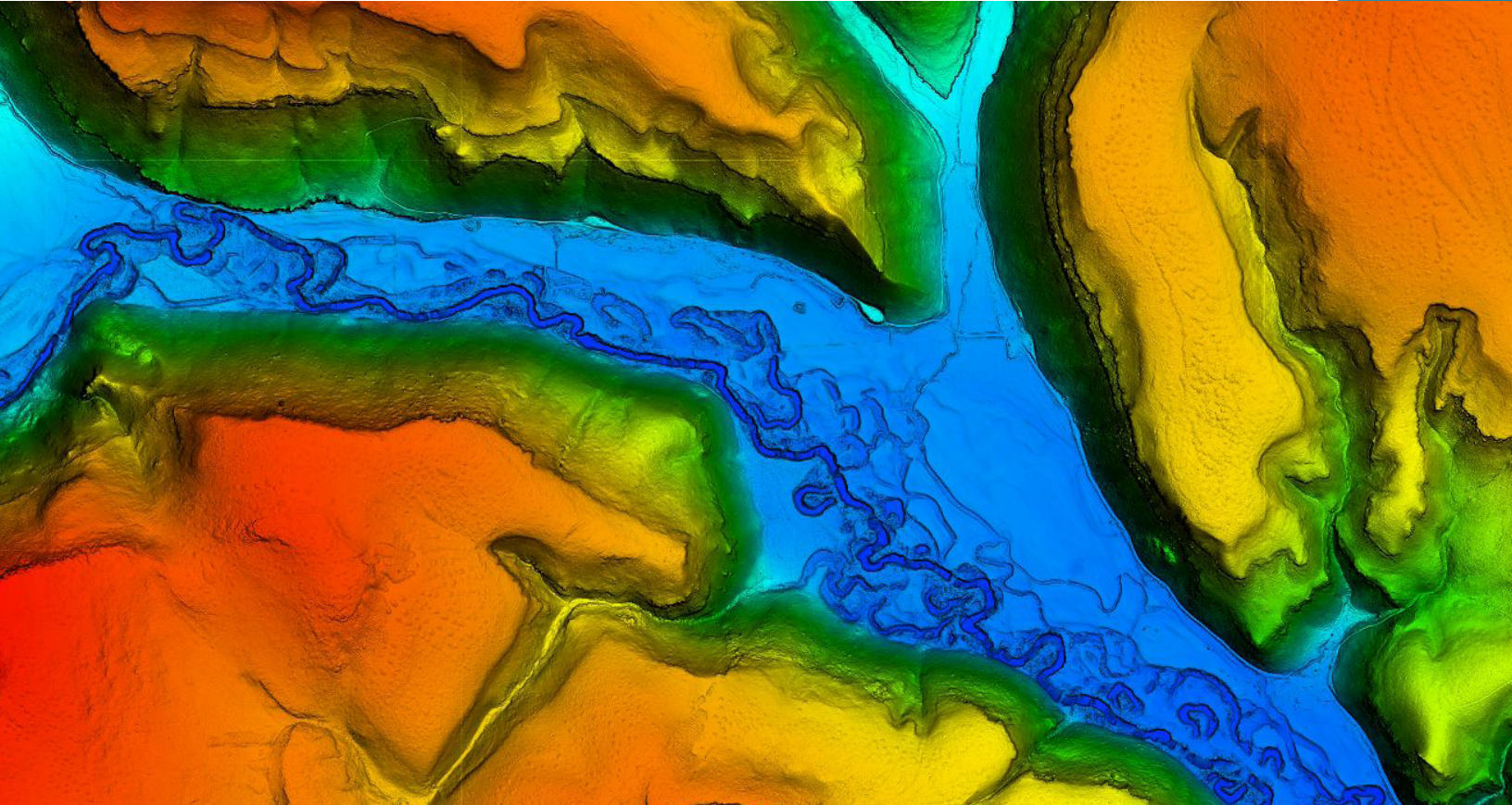# N|V|5 GEOSPATIAL

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OR_NRCS_USGS_2019_D19 LIDAR PROCESSING REPORT

2020

Work Package: 183621
Work Unit: 217483

Submitted: November 2, 2021

Prepared for:

≋USGS
science for a changing world

Prepared by:

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Contents

List of Figures

List of Tables

List of Appendices

Appendix A: Flight Logs

1. Summary / Scope

1.1. Summary

This report contains a summary of the OR_NRCS_USGS_2019_D19, Work Unit 217483 LiDAR acquisition task order, issued by USGS under their Contract G16PC00016 on September 12, 2019. The task order yielded a project area covering approximately 1588 square miles over Oregon. The intent of this document is only to provide specific validation information for the data acquisition/ collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic LiDAR was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
8 pts / m²	2085 m	58.5°	55%	≤ 10 cm

1.3. Coverage

The project boundary covers approximately 1588 square miles over Oregon. Project extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from November 2, 2019 to November 30, 2019 in eleven total lifts. See "Section: 2.4. Time Period" for more details.

1.5. Issues

There were no major issues to report for this project.

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OR_NRCS_USGS_2019_D19 Work Unit 217483 Projected Coordinate System: Oregon Statewide Lambert Horizontal Datum: NAD83(2011) Vertical Datum: NAVD88 (GEOID 12b) Units: International Feet	
Lidar Point Cloud	Classified Point Cloud in .LAS 1.4 format
Rasters	• 3-foot Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format • 3-foot Intensity images in GeoTIFF format
Vectors	Shapefiles (*.shp) • Project Boundary • LiDAR Tile Index Geodatabase (*.gdb) • Continuous Hydro-flattened Breaklines
Reports	Reports in PDF format • Focus on Delivery • Processing Report
Metadata	XML Files (*.xml) • Breaklines • Classified Point Cloud • DEM • Intensity Imagery

OR_NRCS_USGS_2019_D19
Work Unit 217483 Boundary
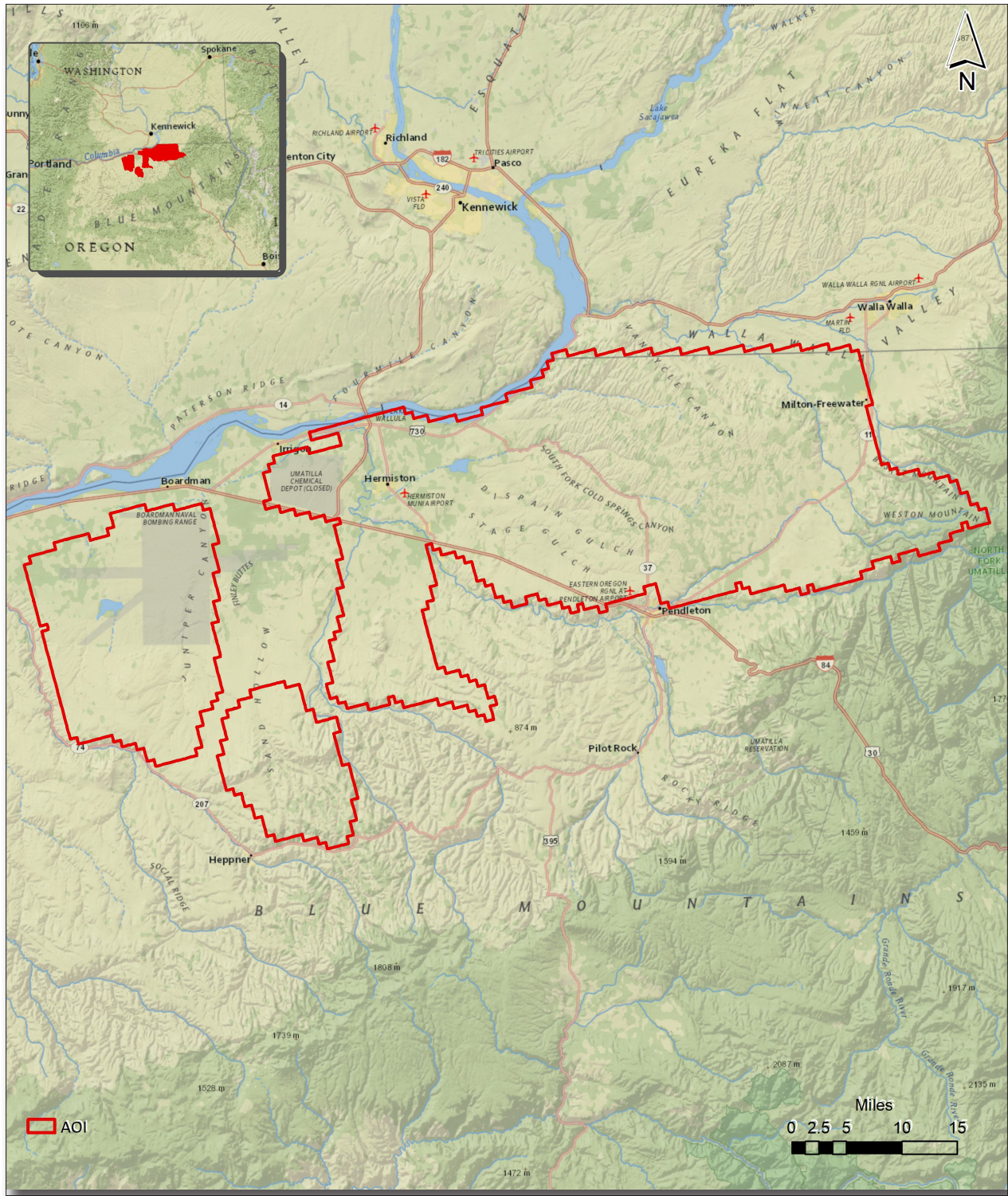
Figure 1. Work Unit Boundary

2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using RiPARAMETER planning software. Planned flight lines are shown in Figure 2.

2.2. LiDAR Sensor

NV5 Geospatial utilized a Riegl VQ1560i LiDAR sensor (Figure 3), serial number 4040 for data acquisition.

The Riegl 1560i system has a laser pulse repetition rate of up to 2 MHz resulting in more than 1.3 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to an unlimited number of targets per pulse from the laser.

A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specifications in Table 2.

OR_NRCS_USGS_2019_D19
Work Unit 217483 Planned Flight Lines
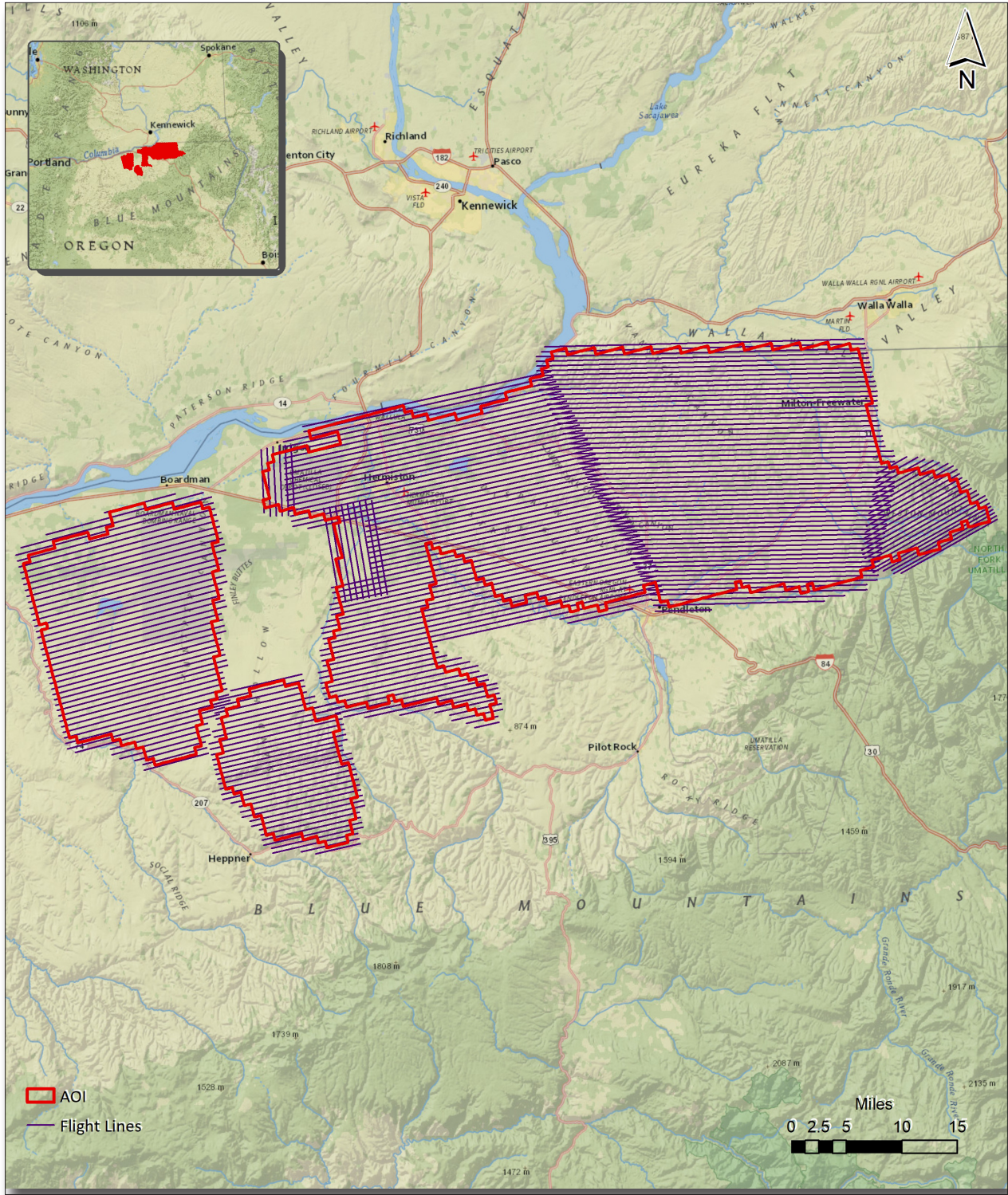
Figure 2. Planned Flight Lines

Table 2. LiDAR System Specifications

		Riegl VQ1560i
Terrain and Aircraft Scanner	Flying Height	2085 m
	Recommended Ground Speed	115 kts
Scanner	Field of View	58.5°
	Scan Rate Setting Used	88.9 Hz
Laser	Laser Pulse Rate Used	500 kHz
	Multi Pulse in Air Mode	yes
Coverage	Full Swath Width	2335.3 m
	Line Spacing	1050.89 m
Point Spacing and Density	Average Point Spacing	0.29 m
	Average Point Density	11.89 pts / m²

Figure 3. Riegl VQ1560i LiDAR Sensors

2.3. Aircraft

All flights for the project were accomplished through the use of customized planes. Plane type and tail numbers are listed below.

LiDAR Collection Planes
- Cessna Caravan, Tail Numbers: N208NR

These aircraft provided an ideal, stable aerial base for LiDAR acquisition. These aerial platforms have relatively fast cruise speeds, which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds, proving ideal for collection of high-density, consistent data posting using a state-of-the-art Riegl VQ1560i LiDAR system. Some of NV5 Geospatial's operating aircraft can be seen in Figure 4 below.

Figure 4. Some of NV5 Geospatial's Planes

2.4. Time Period

Project specific flights were conducted between November 2, 2019 and November 30, 2019. Eleven aircraft lifts were completed. Accomplished lifts are listed below.

- 11022019B (SN4040,N208NR)

- 11032019A (SN4040,N208NR)

- 11042019A (SN4040,N208NR)

- 11092019C (SN4040,N208NR)

- 11102019A (SN4040,N208NR)

- 11162019A (SN4040,N208NR)

- 11202019A (SN4040,N208NR)

- 11212019A (SN4040,N208NR)

- 11242019A (SN4040,N208NR)

- 11262019A (SN4040,N208NR)

- 11302019A (SN4040,N208NR)

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc).

3.2. LiDAR Processing

Applanix + POSPac software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. Applanix POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory" (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

Point clouds were created using the RiPROCESS software. The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. The point cloud is imported into GeoCue distributive processing software. Imported data is tiled and then calibrated using TerraMatch and proprietary software. Using TerraScan, the vertical accuracy of the surveyed ground control is tested and any bias is removed from the data. TerraScan and TerraModeler software packages are then used for automated data classification and manual cleanup. The data are manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler.

DEMs and Intensity Images are then generated using proprietary software. In the bare earth surface model, above-ground features are excluded from the data set. Global Mapper is used as a final check of the bare earth dataset.

Finally, proprietary software is used to perform statistical analysis of the LAS files.

Software	Version
Applanix + POSPac	8.4
RiPROCESS	1.8.6
GeoCue	2017.1.14.1
Global Mapper	19.1;20.1
TerraModeler	20.004
TerraScan	20.011
TerraMatch	20.004

3.3. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.3 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

Table 3. LAS Classifications

	Classification Name	Description
1	Processed, but Unclassified	Laser returns that are not included in the ground class, or any other project classification
2	Bare earth	Laser returns that are determined to be ground using automated and manual cleaning algorithms
7	Low Noise	Laser returns that are often associated with scaterring from reflective surfaces, or artificial points below the ground surface
9	Water	Laser returns that are found inside of hydro features
17	Bridge Deck	Laser returns falling on bridge decks
18	High Noise	Laser returns that are often associated with birds or artificial points above the ground surface
20	Ignored Ground	Ground points that fall within the given threshold of a collected hydro feature.

3.4. Classified LAS Processing

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 flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 20). 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.

Any noise that was identified either through manual review or automated routines was classified to the appropriate class (ASPRS Class 7 and/or ASPRS Class 18) followed by flagging with the withheld bit.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. NV5 Geospatial's 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.

3.5. Hydro-Flattened Breakline Processing

Class 2 LiDAR was 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 streams and rivers using NV5 Geospatial's 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 3 feet was also used around each hydro flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 20).

The breakline files were then translated to Esri file geodatabase 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 Data Reviewer tools and proprietary tools.

3.6. Hydro-Flattened Raster DEM Processing

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 3-foot Raster DEM. Using automated scripting routines within proprietary software, a GeoTIFF file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

3.7. Intensity Image Processing

GeoCue software was used to create the deliverable intensity images. All withheld points were ignored during this process. This helps to ensure a more aesthetically pleasing image. The GeoCue software was then used to verify full project coverage as well. GeoTIFF files with a cell size of 3-foot were then provided as the deliverable for this dataset requirement.

OR_NRCS_USGS_2019_D19
Work Unit 217483 Tile Layout
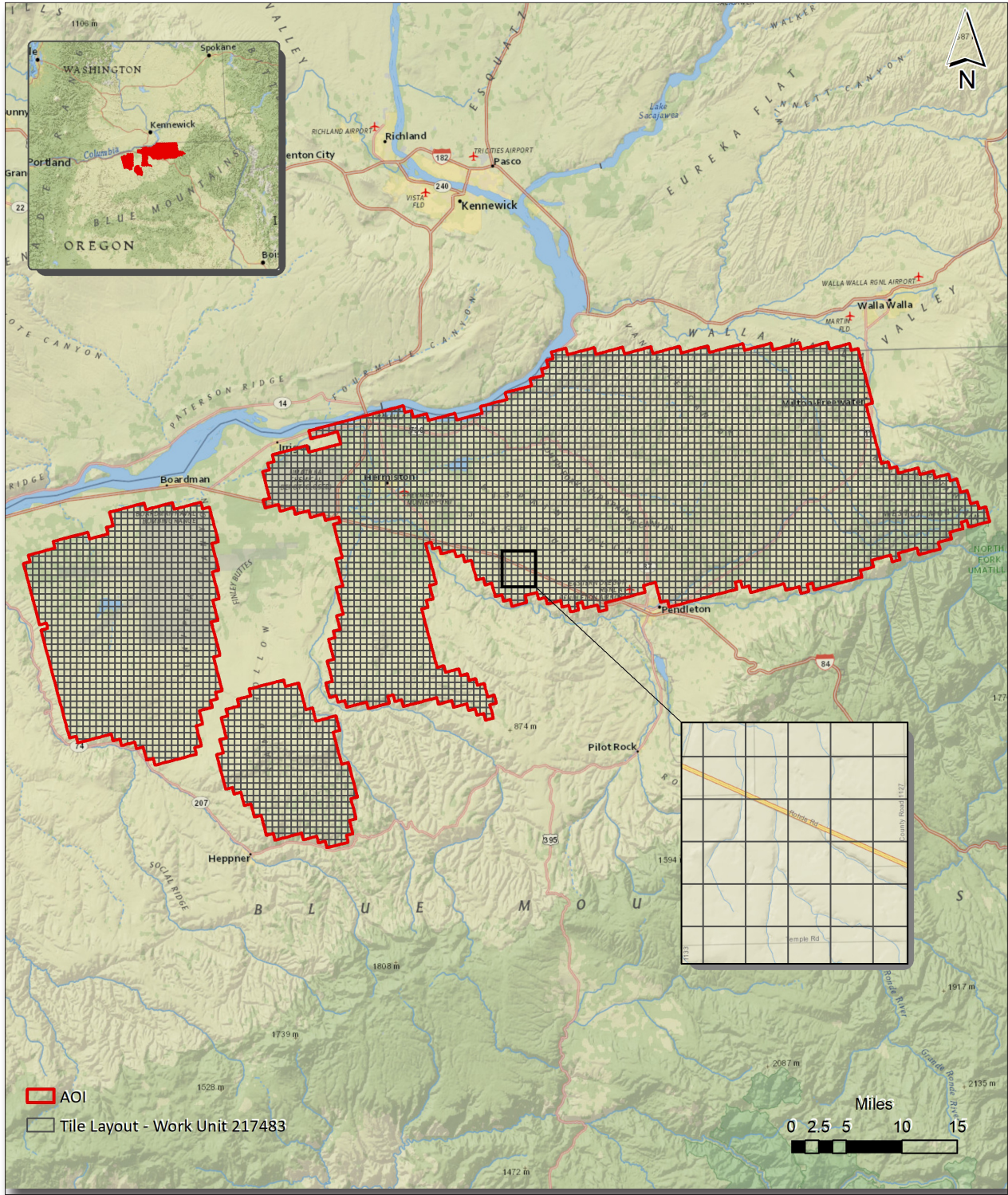
Figure 5. Lidar Tile Layout

4. Project Coverage Verification

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 6.

OR_NRCS_USGS_2019_D19
Work Unit 217483 Lidar Coverage

Figure 6. Lidar Coverage

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Project Report Appendices

The following section contains the appendices as listed in

the OR_NRCS_USGS 2019 D19, Work Unit 217483

LiDAR Processing Report.

Appendix A

Flight Logs

Project: OR NRCS

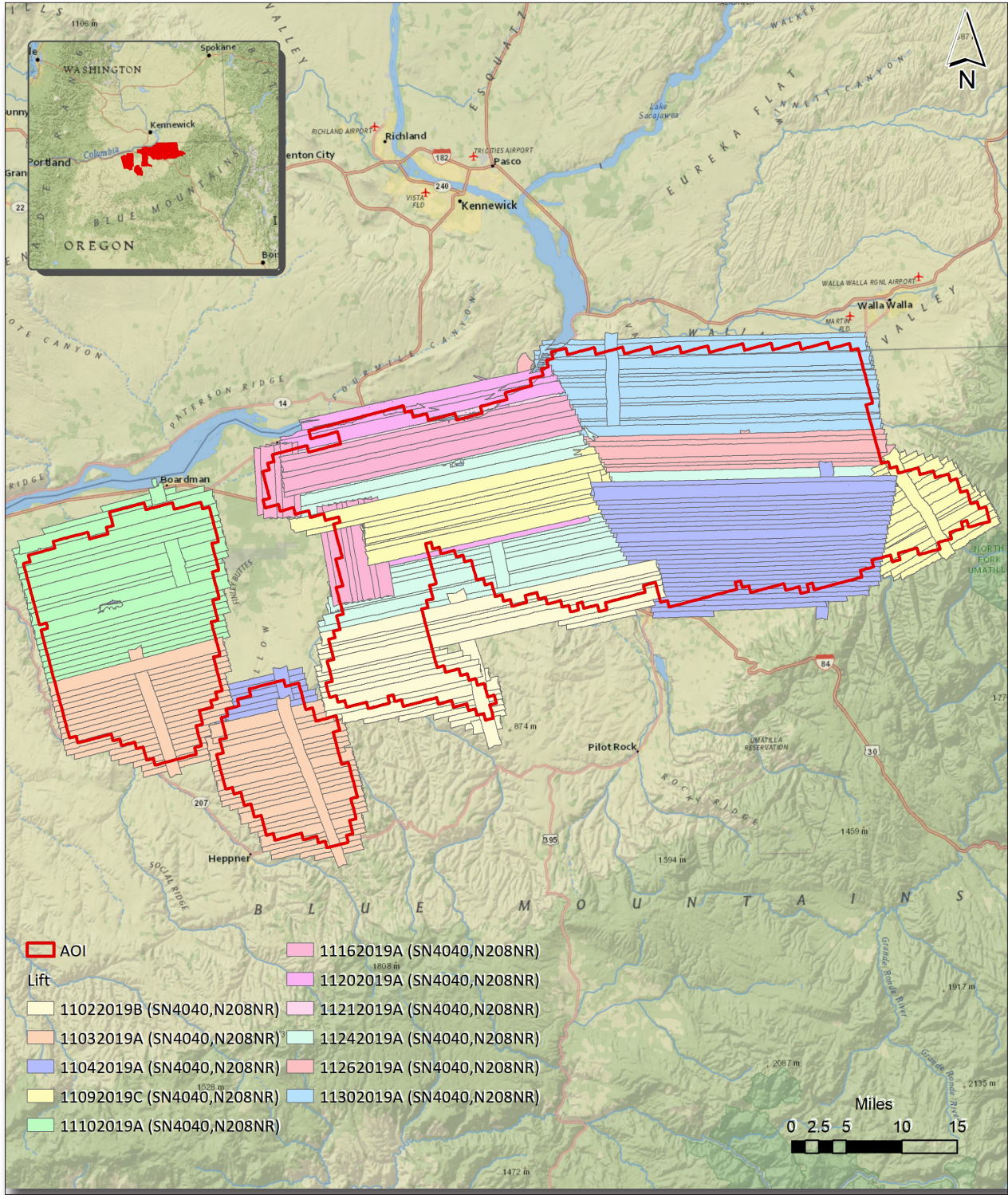| Date	Mission ID	Sensor	Aircraft Make/Model	Aircraft Tail Number	Flight Plan	Lines Flown	Flight 1 Wheels Up (PDT)	Flight 1 Wheels Down (PDT)	Flight 1 Begin Hobbs	Flight 1 End Hobbs	Flight 1 Total Hobbs	Flight 2 Wheels Up	Flight 2 Wheels Down	Flight 2 Begin Hobbs	Flight 2 End Hobbs	Flight 2 Total Hobbs	Daily Hobbs	Operator	Pilot	Base of Operations (airport, KXXX)	Notes
11/2/2019	20191102_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Burns1560i_QL1, OR_NRCS_Pendleton_1560i_QL1	116-127, 140-164.	10:07:00 AM	12:48:00 PM	6921.9	6924.6	2.7	2:11:00 PM	6:18:00 PM	6924.6	6928.7	4.1	6.80	Dwight Iverson	Dave Wagner	KPDT	Flew on Burns & Pendleton
11/3/2019	20191103_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Pendleton_1560i_QL1	220-238, 16-43	9:55:00 AM	4:06:00 PM	6928.7	6934.9	6.2					0	6.20	Dwight Iverson	Dave Wagner	PDT	110219, & Pendleton 110219-110319 tomorrow.
11/4/2019	20191104_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Pendleton_1560i_QL1	10-15, 73-99 165-187, 118-	10:18:00 AM	4:35:00 PM	6934.9	6941.2	6.3					0	6.30	Dwight Iverson	Dave Wagner	KALW	Flew on Pendleton project
11/9/2019	20191109_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Pendleton_1560i_QL1	127	9:59:00 AM	3:45:00 PM	6965.7	6971.5	5.8					0	5.80	Dwight Iverson	Spencer Napor	ALW	Flew on Pendleton project
11/10/2019	20191110_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Pendleton_1560i_QL1	194-219	2:26:00 PM	6:45:00 PM	6971.5	6975.8	4.3					0	4.30	Dwight Iverson	Spencer Napor	ALW	Flew on Pendleton project after wx improved.
11/16/2019	20191116_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	20191116_NRCS_Pendleton	1-9, 106-111, 188-193	9:00:00 AM	1:10:00 PM	6975.8	6979.9	4.1	2:05:00 PM	2:45:00 PM	6979.9	6980.5	0.6	4.70	Liz Bartholomew	Eric Petersen	CVO	patches of clouds in AOI, jumped around and acquired a modest chunk. Flew to CVO for scheduled mx.
11/20/2019	20191120_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	20191116_NRCS_Pendleton	100-103	10:00:00 AM	1:00:00 PM	6980.5	6983.4	2.9					0	2.90	Liz Bartholomew	Eric Petersen	ALW	maintenance. Thwarted by clouds after a flying a handful of lines.
11/21/2019	20191121_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	20191116_NRCS_Pendleton	103-105	11:45:00 AM	4:40:00 PM	6983.4	6988.3	4.9					0	4.90	Liz Bartholomew	Eric Petersen	ALW	couple of lines on the project in the afternoon.
11/24/2019	20191124_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	20191124_NRCS_Pendleton	112-117, 127-139, 72 & 71	9:00:00 AM	1:50:00 PM	6991.2	6996	4.8					0	4.80	Liz Bartholomew	Eric Petersen	KALW	Finally did not wake up in a sea of fog. Low lying clouds throughout certain sections of AOI. We were able to clean up two blocks, now chipping away at final block. ~7 hrs left.
11/26/2019	20191126_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	20191126_NRCS_Pendlton	70-64	10:00:00 AM	12:00:00 PM	6996	6998	2					0	2.00	Liz Bartholomew	Eric Petersen	KALW	throughout day so we went for it. Acquired a handful of lines before AOI was consumed by clouds.
11/30/2019	20191130_SN4040	Riegl VQ-1560i S2224040	Cessna Caravan 208B	N208NR	OR_NRCS_Pendleton_VQ1560i	44-63, 70	8:07:00 AM	1:16:00 PM	7003.5	7008.6	5.1					0	5.10	Stephanie Cohee	Chris LaRosa	KALW	Completing Pendleton project, and ending the day at KALW.