# OLC Crooked Ochoco - Final Delivery


WSI Applied Remote Sensing and Analysis

quantumspatial.com

October 7, 2014

Data collected for:

Department of Geology and Mineral Industries

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WSI Applied Remote Sensing and Analysis

# Contents



Base station set up over survey monument CROOK_09

# Project Overview

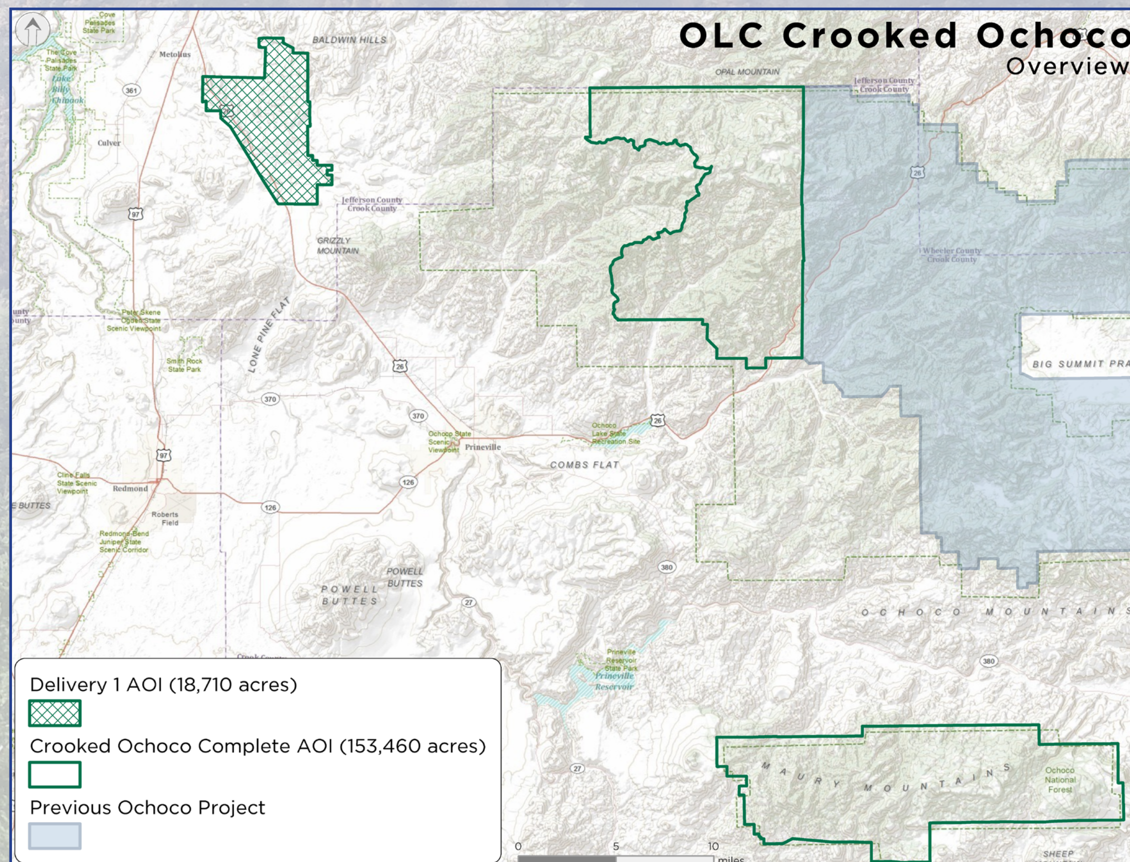
WSI, a Quantum Spatial company, has collected Light Detection and Ranging (LiDAR) data for the Oregon LiDAR Consortium (OLC) Crooked Ochoco study area. This study area is adjacent to the Ochoco study area delivered July 31, 2013. The northwestern section of Crooked Ochoco was acquired before snow fell in the study area at the end of 2013. Acquisition of the remaining areas was completed in summer 2014.

The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

In September and December 2013, and May and June 2014, WSI employed remote-sensing lasers in order to obtain a total area flown of 159,270 acres. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products created include LiDAR point cloud data, one meter digital elevation models of bare earth ground model and highest-hit returns, intensity rasters, ground density rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC).[1]

| Crooked Ochoco Data | |
|---|---|
| Acquisition Dates | 9/27/2013 and 12/11/2013<br>5/3/14, 5/7/14, 5/11/14, 5/12/14<br>6/8/14, 6/9/14, 6/10/14, 6/18/14, 6/19/14 |
| Area of Interest | 153,460 acres |
| Total Area Flown | 159,270 acres |
| Projection | Oregon Statewide<br>Lambert Conformal Conic |
| Datum: horizontal & vertical | NAD83 (2011)<br>NAVD88 (Geoid 12A) |
| Units | International Feet |




1 http://www.oregon.gov/DAS/EISPD/GEO/pages/coordination/projections/projections.aspx

# Aerial Acquisition

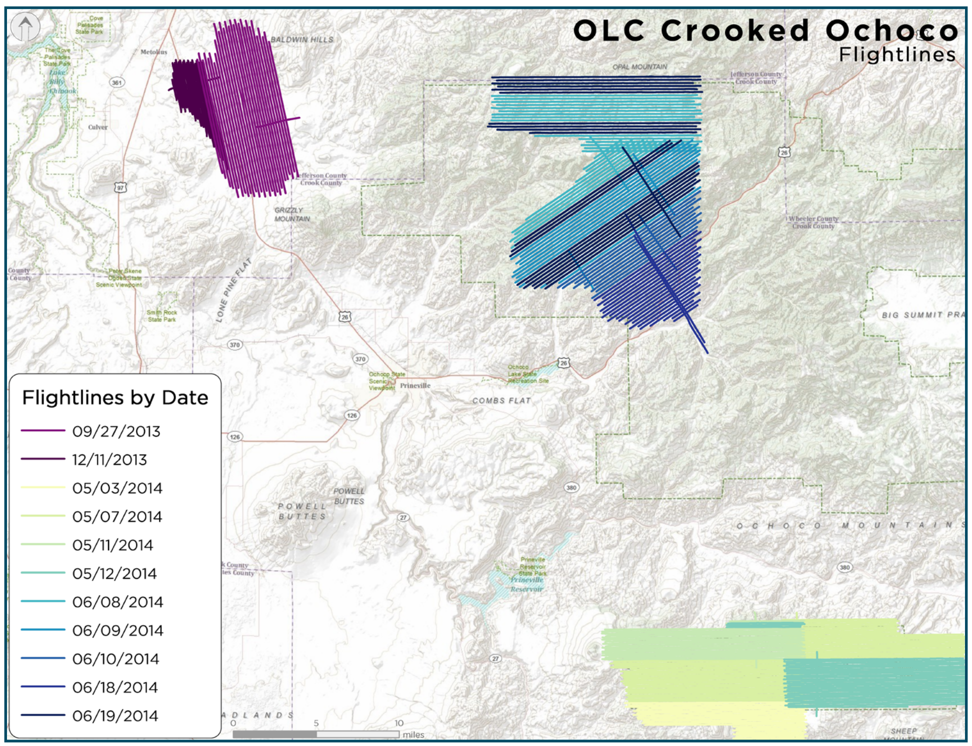
## LiDAR Survey

The LiDAR survey occurred on September 27, 2013 utilizing a Leica ALS 50 sensor mounted in a Piper Navajo, and on December 11, 2013, utilizing a Leica ALS 70 sensor mounted in a Cessna Caravan. In May 2014 LiDAR was collected by a Leica ALS 60 sensor mounted in a Cessna Caravan and in June 2014 by a Leica ALS 70 sensor mounted in a Partenavia P68. The systems were programmed to emit single pulses at a variable rate and were flown at a variable height above ground level (AGL), capturing a scan angle of 15 degrees from nadir (field of view equal to 30 degrees). These settings were developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and was measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is described as pitch, roll, and yaw (heading) and was measured 200 times per second (200 hertz) from an onboard inertial measurement unit (IMU).

The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results during the data processing stage. They were also in constant communication with the ground crew to ensure proper ground GPS coverage for data quality. The LiDAR coverage was completed with no data gaps or voids, barring non-reflective surfaces (e.g., open water, wet asphalt). All necessary measures were taken to acquire data under good conditions (e.g., minimum cloud decks) and in a manner (e.g., adherence to flight plans) that prevented the possibility of data gaps. All WSI LiDAR systems are calibrated per the manufacturer and our own specifications, and tested by WSI for internal consistency for every mission using proprietary methods.

Project Flightlines




| Crooked Ochoco LiDAR Acquisition Specs | |
|---|---|
| Aircraft | September 2013: Piper Navajo<br>December 2013: Cessna Caravan<br>May 2014: Cessna Caravan<br>June 2014: Partenavia P68 |
| Sensor | September 2013: Leica ALS 50<br>December 2013: Leica ALS 70<br>May 2014: Leica ALS 60<br>June 2014: Leica ALS 70 |
| Coverage | 100% Overlap with 65% Sidelap |
| Field of View (FOV) | 30° |
| Targeted Pulse Density | ≥ 8 pulses per square meter |

# Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over thirteen monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify daily variance. Multiple sessions were processed over the same monument to confirm antenna height measurements and reported position accuracy.

| Monument Accuracy | |
|---|---|
| FGDC-STD-007.2-1998 Rating | |
| St Dev NE | 0.010 m |
| St Dev z | 0.050 m |

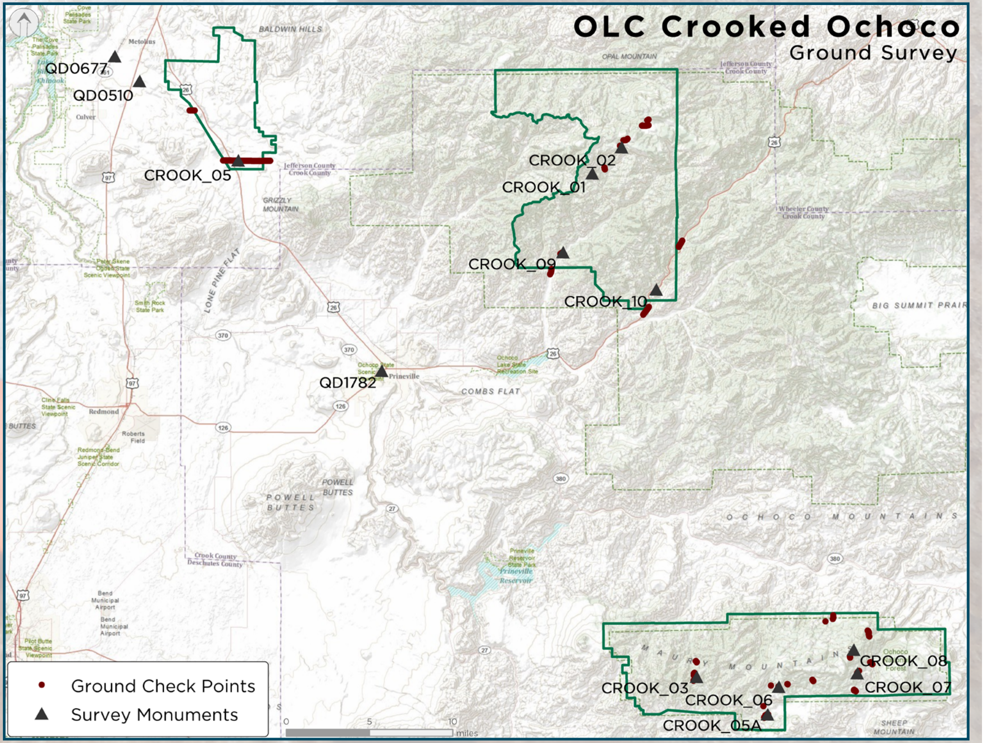
## Instrumentation

For this study area all Global Navigation Satellite System (GNSS) survey work utilized a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points. The Trimble GPS R8 unit is used primarily for real time kinematic (RTK) work but can also be used as a static receiver. For RTK data, the collector began recording after remaining stationary for five seconds then calculated the pseudo range position from at least three epochs with the relative error under 1.5 centimeters horizontal and 2.0 centimeters vertical. All GPS measurements were made with dual frequency L1-L2 receivers with carrier-phase correction.

## Monumentation

Existing and established survey benchmarks serve as control points during LiDAR acquisition, including those previously set by WSI. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own monuments. These monuments are spaced at a minimum of one mile and every effort is made to keep them within the public right of way or on public lands. If monuments are necessary on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a 2 inch diameter aluminum cap stamped "Watershed Sciences, Inc. Control." Ten new monuments were established and occupied for the Crooked Ochoco study area (see Monument table at bottom left).

| Monuments | | | |
|---|---|---|---|
| | Datum NAD 83 (2011) | | |
| Name | Latitude | Longitute | Ellipsoid Height (m) |
| CROOK_01 | 44˚ 28' 21.29663 | -120˚ 36' 32.36005" | 1447.597 |
| CROOK_02 | 44˚ 29' 42.84741" | -120˚ 34' 24.15181" | 1630.443 |
| CROOK_03 | 44˚ 02' 04.01815" | -120˚ 29' 06.00812" | 1626.593 |
| CROOK_05 | 44˚ 29' 02.96147" | -121˚ 02' 21.56094" | 926.298 |
| CROOK_05A | 44˚ 00' 05.98823" | -120˚ 23' 59.65190" | 1512.436 |
| CROOK_06 | 44˚ 01' 31.99780" | -120˚ 23' 10.26445" | 1655.831 |
| CROOK_07 | 44˚ 02' 12.79860" | -120˚ 17' 29.31869" | 1549.499 |
| CROOK_08 | 44˚ 03' 26.48121" | -120˚ 17' 44.45762" | 1836.873 |
| CROOK_09 | 44˚ 24' 14.82228" | -120˚ 38' 41.84905" | 1036.997 |
| CROOK_10 | 44˚ 22' 17.65252" | -120˚ 31' 55.24109" | 1100.696 |
| QD0510 | 44˚ 33' 10.67113" | -121˚ 09' 34.38641" | 774.539 |
| QD0677 | 44˚ 34' 28.09372" | -121˚ 11' 23.51557" | 755.861 |
| QD1782 | 44˚ 18' 04.56990" | -120˚ 51' 54.05802" | 952.364 |



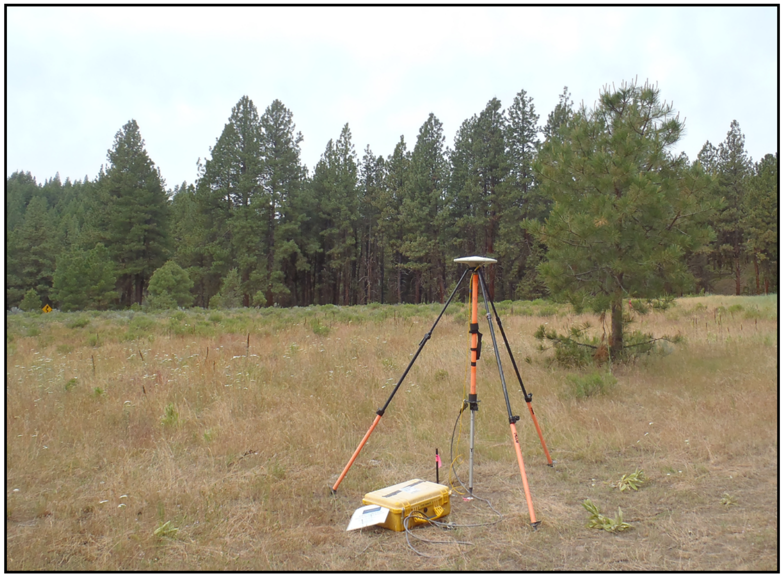
## Methodology

Each aircraft is assigned a ground crew member with two R7 receivers and an R8 receiver. The ground crew vehicles are equipped with standard field survey supplies and equipment including safety materials. All control monuments are observed for a minimum of two survey sessions lasting no fewer than two hours. At the beginning of every session the tripod and antenna are reset, resulting in two independent instrument heights and data files. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna.

WSI uses two methods for collecting Ground Check Points (GCP): Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). All GCP measurements are made during periods with a Position Dilution of Precision (PDOP) of less than 3.0 and in view of at least six satellites by the stationary reference and roving receiver. GCP positions are collected on 20 percent of the flight lines and on bare earth locations such as paved, gravel or stable dirt roads, and other locations where the ground is clearly visible (and is likely to remain visible) from the sky during the data acquisition and GCP measurement period(s). In order to facilitate comparisons with LiDAR survey points, GCP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GCPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations.

Multiple differential GPS units are used in the ground based real-time kinematic portion of the survey. To collect accurate ground surveyed points, a GPS base unit is set up over monuments to broadcast a kinematic correction to a roving GPS unit. The ground crew uses a roving unit to receive radio-relayed kinematic corrected positions from the base unit. The WSI ground survey allows precise location measurement (≤1.5 centimeters).

Left: Ground professional collecting Ground Check Points in the Crooked Ochoco study area



Left and right: R7 receivers in the Crooked Ochoco study area

# Accuracy

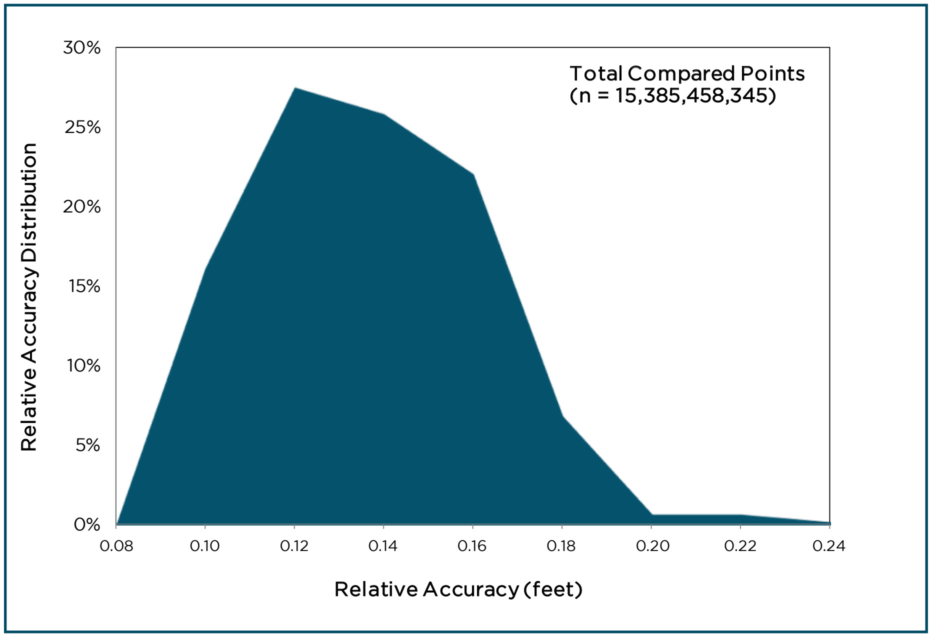
## Relative Accuracy

Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (<10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift.

Relative accuracy statistics are based on the comparison of 422 flightlines and over 15 billion LiDAR points. Relative accuracy is reported for the entire study area.

| Relative Accuracy Calibration Results | |
|---|---|
| Project Average | 0.13 ft. (0.04 m) |
| Median Relative Accuracy | 0.13 ft. (0.04 m) |
| 1σ Relative Accuracy | 0.14 ft. (0.04 m) |
| 2σ Relative Accuracy | 0.17 ft. (0.05 m) |

Relative Accuracy Distribution




**Below:** Survey monument QD0510 placed in 1938

## Vertical Accuracy

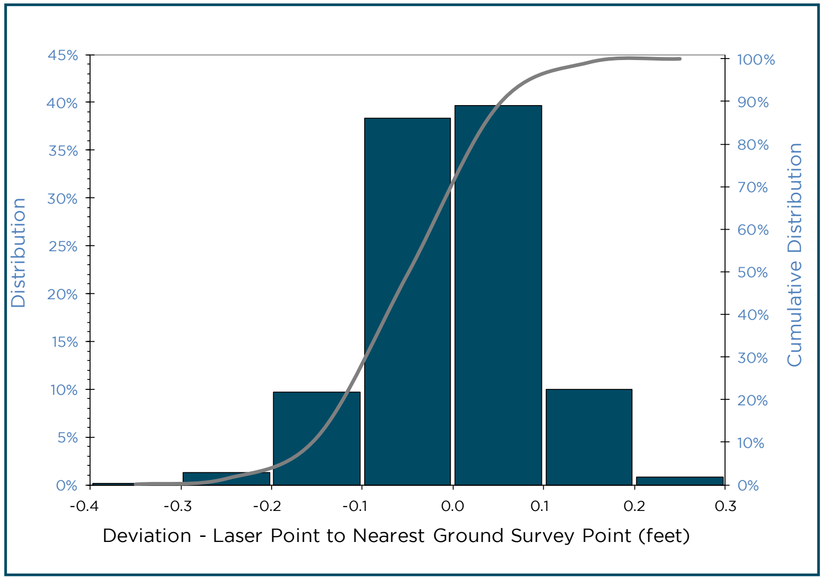
Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known Ground Check Points to the closest laser point. Vertical accuracy statistical analysis uses ground check points in open areas where the LiDAR system has a "very high probability" that the sensor will measure the ground surface and is evaluated at the 95th percentile.

For the Crooked Ochoco study area, 2,413 GCPs were collected.

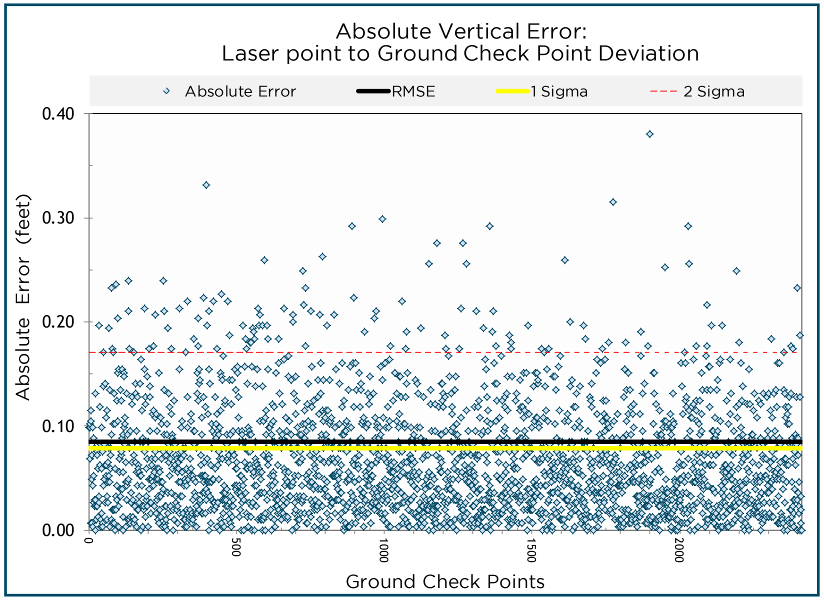
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed to the right.

| Vertical Accuracy Results | |
|---|---|
| Sample Size (n) | 2,413 GCPs |
| Root Mean Square Error | 0.08 ft (0.03 m) |
| 1 Standard Deviation | 0.08 ft (0.02 m) |
| 2 Standard Deviations | 0.17 ft (0.05 m) |
| Average Deviation | 0.00 ft (0.00 m) |
| Minimum Deviation | -0.38 ft (-0.12 m) |
| Maximum Deviation | 0.28 ft (0.08 m) |

Vertical Accuracy Distribution




Absolute Vertical Error



# Density

## Pulse Density

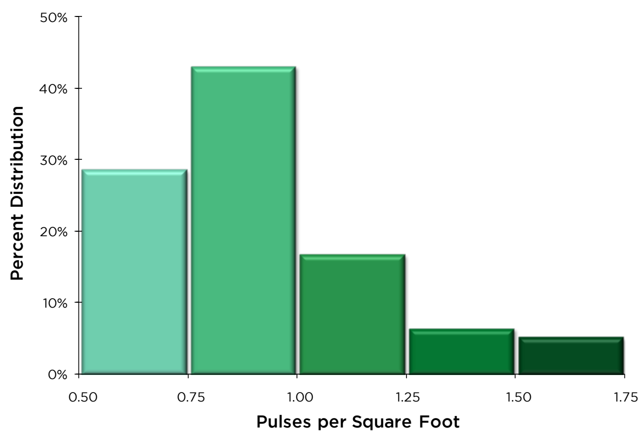
Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on first return laser pulse density and ground-classified laser point density.

| Average Point Densities | | | |
|---|---|---|---|
| Pulses per square foot | Pulses per square meter | Ground points per square foot | Ground points per square meter |
| 0.90 | 9.74 | 0.17 | 1.81 |

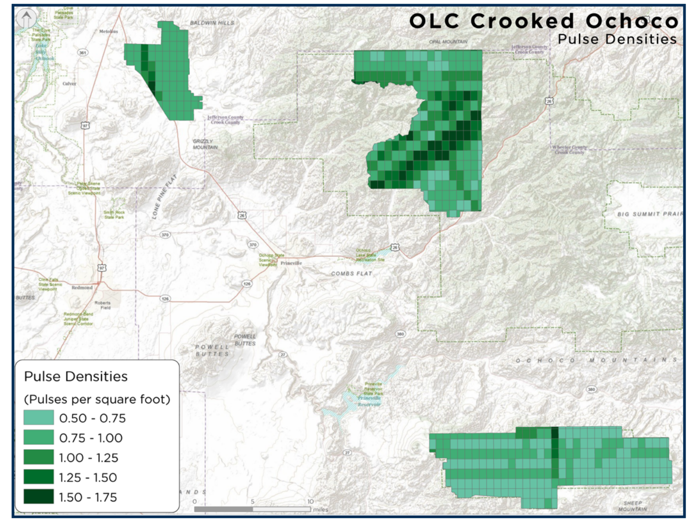
## Ground Density

Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries.

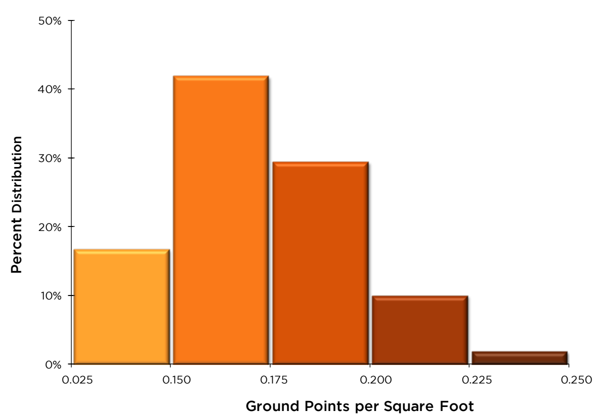
Pulse Density Distribution



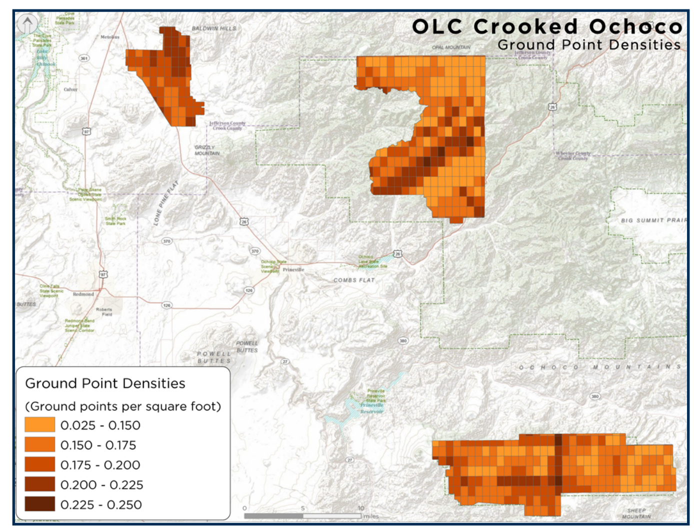

Average Pulse Density per 0.75' USGS Quad
(color scheme aligns with density chart)




Ground Density Distribution




Average Ground Point Density per 0.75' USGS Quad
(color scheme aligns with density chart)



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# PLS Certificate

WSI provided LiDAR  Services for OLC's Crooked Ochoco project as described in this report.

I, Matthew Boyd, have reviewed the attached report for completeness and herby state that it is a complete and accurate report of this project.

Mathew Boyd
CIO
WSI, a Quantum Spatial company

I, Christopher W. Brown, being duly registered as a Professional Land Surveyor in the state of Oregon, say that I hereby certify the methodologies and results of the attached LiDAR project, and that Static GPS occupations on the Base Stations during airborne flights and RTK survey on hard-surface, were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between april 25, 2014 and June 19, 2014.

Christopher W. Brown, PLS Oregon & Washington
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Portland, OR 97204

REGISTERED
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LAND SURVEYOR

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