2015 OLC Umpqua Study Area

August 12, 2016

Data collected for:
Oregon Department of Geology and Mineral Industries

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Project Overview

QSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data describing the Oregon LiDAR Consortium's (OLC) Umpqua Study Area. The Umpqua area of interest (AOI) shown in Figure 1 encompasses 1,414,070 acres.

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.

LiDAR data occured between February 14 and November 12, 2015. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter. Final products are listed in page 3.

QSI acquires and processes data in the most current, NGS-approved datums and geoid. For Umpqua, all final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC),[1] using the NAD83 (2011) horizontal datum and the NAVD88 (Geoid 12A) vertical datum, with units in International feet.

Table 1: Umpqua delivery details

Umpqua	
Acquisition Dates	2/14/2015 - 11/12/2015*
Buffered Area of Interest	1,414,070 acres
Projection	OGIC
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

*See page four for specific acquisition dates.

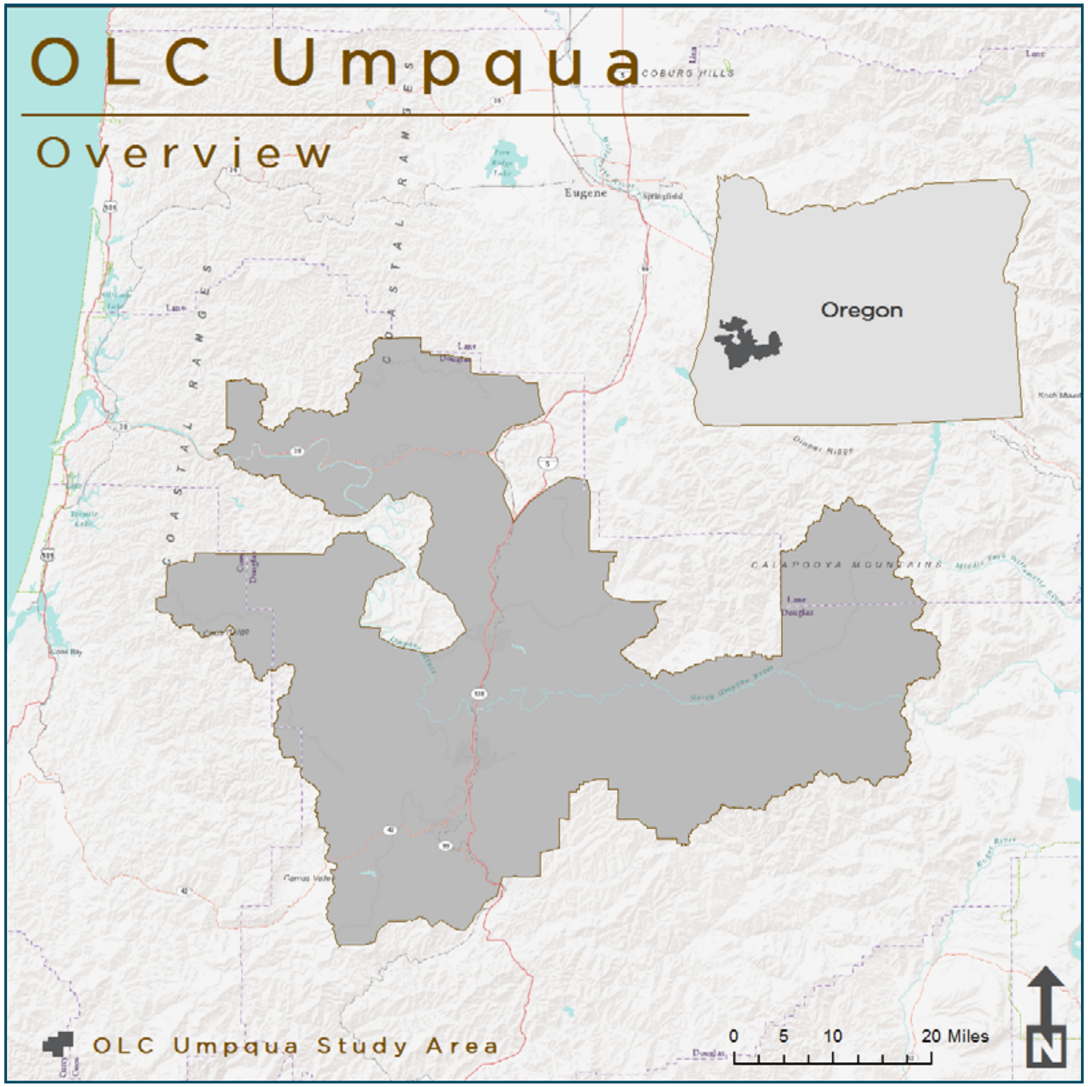


Figure 1: Umpqua study area location

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

Deliverable Products

Table 2: Products delivered for the OLC Umpqua study area.

Umpqua Projection: OGIC Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12A) Units: International Feet	
Points	LAS v 1.2 tiled by 0.0375 minute USGS quadrangles • Default (1), ground (2), and bridge (17) classfied points • RGB color extracted from NAIP imagery • Intensities
Rasters	3 foot ESRI GRID tiled by 7.5 minute USGS quadrangles • Bare earth model • Highest hit model • LiDAR ground density images 1.5 foot GeoTiffs tiled by 7.5 minute USGS quadrangles • Intensity images
Vectors	Shapefiles (*.shp) • Data extent (TAF/BAOI) • Area of interest (AOI) • BAOI tile index of 0.0375 minute USGS quadrangles • BAOI tile index of 7.5 minute USGS quadrangles
Metadata	• FGDC compliant metadata for all data products
Projection: UTM Zone 10N Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12A) Units: Meters	
Vectors	• Reserved ground survey points • Reserved vegetated ground survey points for vegetated vertical accuracy (VVA) testing • Ground survey points • Monuments • Acquisition flightlines

Aerial Acquisition

LiDAR Survey

The LiDAR survey utilized a Optech Orion H sensor mounted in a Partenavia P68, and two Leica ALS 80 sensors, each mounted in a Cessna Caravan. For system settings, please see Table 3. These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions of terrain, land cover, and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60 percent with at least 100 percent overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output dataset.

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

Table 3: Umpqua aquisition specifications

OLC Umpqua		
Sensors Deployed	Optech Orion H	Leica ALS 80
Aircraft	Partenavia P68	Cessna Caravan
Survey Altitude (AGL)	1,200 m	1,500 m
Pulse Rate	175 kHz	369.2 kHz
Pulse Mode	Multi (MPiA)	Single (SPiA)
Field of View (FOV)	30°	30°
Scan Rate	66 Hz	58.4 Hz
Overlap	100% overlap with 60% sidelap	100% overlap with 60% sidelap

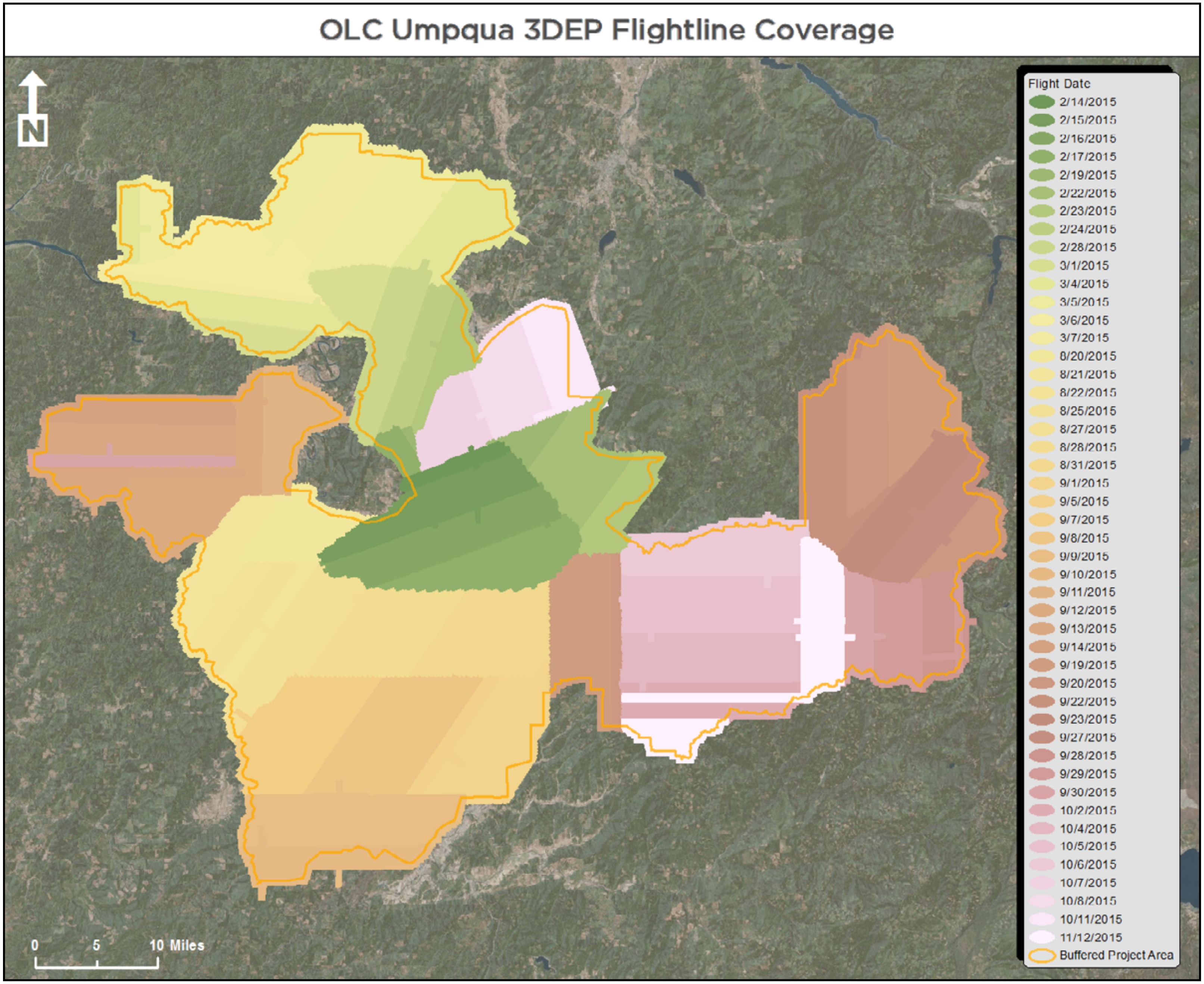


Figure 2: Umpqua aquisition dates and flightline coverage.

Ground Survey

Ground control surveys and ground survey points (GSPs) were collected to support the airborne acquisition. Ground control data are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data.

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R6 and R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R6, R8, and R10 GNSS receivers. See Table 5 for specifications of equipment used.

Monumentation

The spatial configuration of ground survey monuments provided redundant control within 13 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground survey points using real time kinematic (RTK) and post processed kinematic (PPK) survey techninques. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. New monumentation was set using 5/8" x 30" rebar topped with stamped 2-1/2" aluminum caps. QSI's professional land surveyor, Evon Silvia (OR PLS #81104) oversaw and certified the establishment of all monuments.

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each monument. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy. Table 6 provides the list of monuments used in the Umpqua study area.

Methodology

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK), and Post-Processed Kinematic (PPK) survey techniques. For RTK surveys, a base receiver is positioned at a nearby monument to broadcast a kinematic correction to a roving receiver; for PPK surveys, however, these corrections are post-processed. All GSP measurements are made during periods with a Position Dilution of Precision (PDOP) no greater than 3.0 and in view of at least six satellites for both receivers. Relative errors for the position must be less than 1.5 centimeters horizontal and 2.0 centimeters vertical in order to be accepted.

In order to facilitate comparisons with high quality LiDAR data, GSP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GSPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GSPs were collected within as many flight lines as possible; however, the distribution depended on ground access constraints and may not be equitably distributed throughout the study area.

Table 5: Ground survey instrumentation

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R6	Integrated GNSS Antenna R6	TRM_R6	Static & Rover
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8 GNSS	Integrated Antenna R8 Model 2	TRMR8_GNSS	Static & Rover
Trimble R10 GNSS	Integrated GNSS Antenna R10	TRM_R10	Rover

Table 4: Monument accuracy

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.05 m
St Dev z	0.05 m

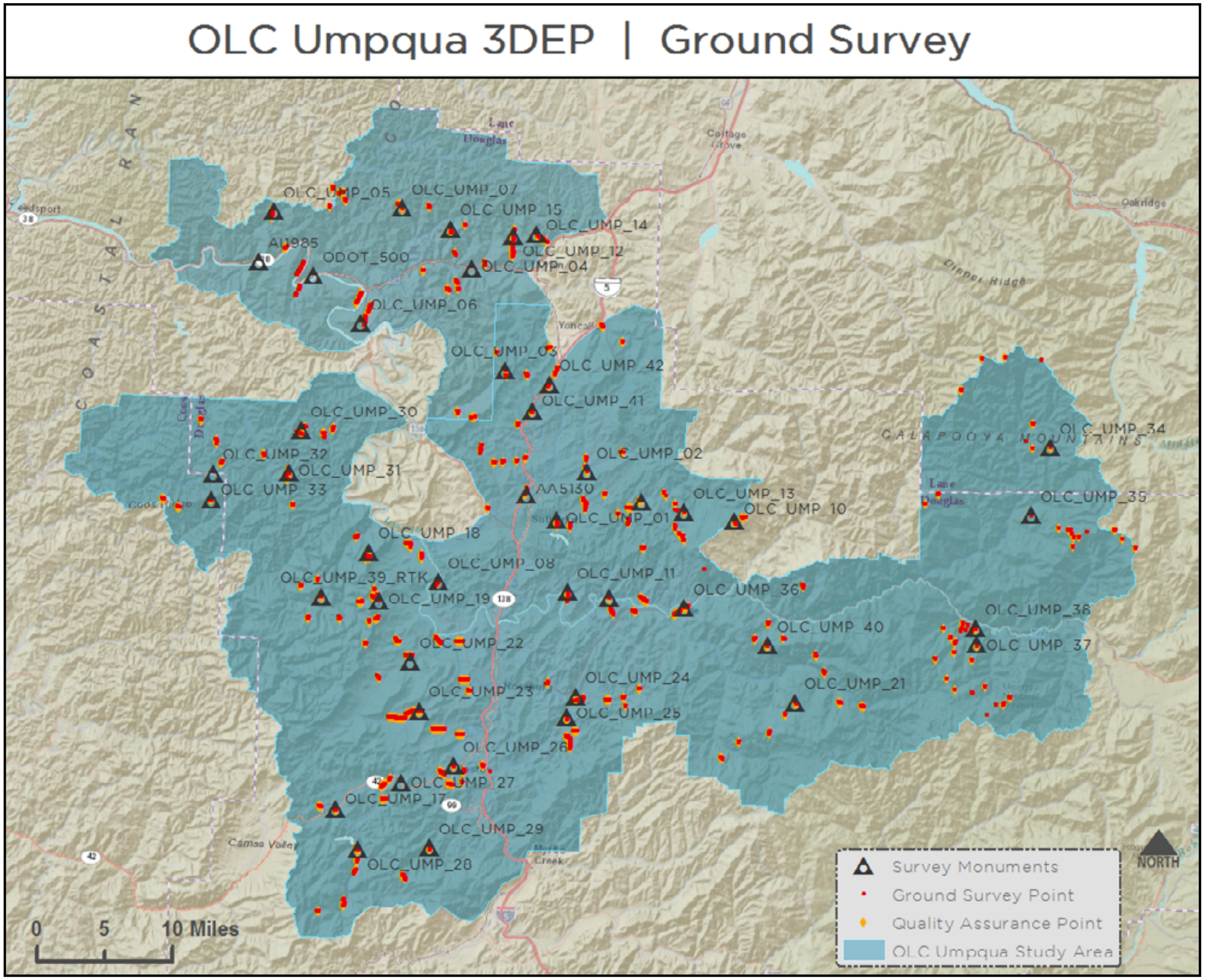


Figure 3: Umpqua study area ground control

Figure 4: Monument set up over base station OLC_UMP_19 within the OLC Umpqua study area.

Table 6: OLC Umpqua monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
AA5130	43° 25' 17.33122"	-123° 19' 10.72364"	125.743	149.075
AI1985	43° 39' 37.49483"	-123° 43' 31.95457"	-1.228	22.453
DOUGLAS_CO_ RP_P265+49.88	43° 25' 06.36148"	-123° 09' 01.37679"	201.222	224.504
ODOT_500	43° 38' 51.21470"	-123° 38' 41.74051"	16.939	40.49
OLC_UMP_01	43° 23' 44.82220"	-123° 16' 27.25272"	145.112	168.485
OLC_UMP_02	43° 26' 53.24329"	-123° 13' 54.80885"	126.769	150.029
OLC_UMP_03	43° 33' 13.17698"	-123° 21' 27.11974"	458.863	481.873
OLC_UMP_04	43° 39' 41.05696"	-123° 24' 39.72993"	55.567	78.634
OLC_UMP_05	43° 42' 53.55857"	-123° 42' 26.07732"	263.094	286.625
OLC_UMP_06	43° 35' 54.99811"	-123° 34' 21.17735"	75.666	99.085
OLC_UMP_07	43° 43' 23.87912"	-123° 31' 04.83455"	377.28	400.386
OLC_UMP_08	43° 19' 28.83046"	-123° 26' 40.46209"	96.626	120.255
OLC_UMP_09	43° 18' 52.07103"	-123° 11' 35.51473"	190.812	214.303
OLC_UMP_10	43° 24' 01.80351"	-123° 00' 47.21907"	1032.063	1055.202
OLC_UMP_11	43° 19' 07.54670"	-123° 15' 16.63695"	151.999	175.498
OLC_UMP_12	43° 41' 52.07184"	-123° 21' 06.21896"	97.634	120.666
OLC_UMP_13	43° 24' 28.91937"	-123° 05' 15.70600"	505.676	528.9
OLC_UMP_14	43° 42' 00.40219"	-123° 19' 01.80888"	100.274	123.316
OLC_UMP_15	43° 42' 11.91415"	-123° 26' 39.72648"	414.061	437.073
OLC_UMP_17	43° 04' 39.58478"	-123° 34' 56.22247"	202.49	226.589
OLC_UMP_18	43° 21' 14.98059"	-123° 32' 49.58361"	440.806	464.305
OLC_UMP_19	43° 18' 08.74247"	-123° 31' 50.76754"	614.711	638.309
OLC_UMP_21	43° 12' 30.23889"	-122° 54' 57.19653"	835.157	858.564
OLC_UMP_22	43° 14' 17.72074"	-123° 28' 53.82756"	132.43	156.198
OLC_UMP_23	43° 11' 10.16741"	-123° 27' 52.70901"	172.471	196.306
OLC_UMP_24	43° 12' 25.85142"	-123° 14' 11.14332"	170.262	193.949
OLC_UMP_25	43° 11' 05.73067"	-123° 14' 59.63453"	174.861	198.587
OLC_UMP_26	43° 07' 42.82126"	-123° 24' 43.91210"	152.524	176.462
OLC_UMP_27	43° 06' 32.34553"	-123° 29' 16.89755"	187.863	211.843
OLC_UMP_28	43° 02' 09.42913"	-123° 32' 53.65212"	214.625	238.693
OLC_UMP_29	43° 02' 25.15936"	-123° 26' 34.04196"	209.327	233.329
OLC_UMP_30	43° 28' 53.95794"	-123° 39' 14.24190"	273.29	296.749
OLC_UMP_31	43° 26' 08.56347"	-123° 40' 08.50814"	581.298	604.791
OLC_UMP_32	43° 25' 53.97263"	-123° 46' 48.22433"	507.18	530.808
OLC_UMP_33	43° 24' 13.53459"	-123° 46' 56.79178"	665.631	689.298
OLC_UMP_34	43° 29' 18.35980"	-122° 33' 05.85648"	1066.679	1089.422
OLC_UMP_35	43° 24' 55.60652"	-122° 34' 40.00558"	874.077	896.957
OLC_UMP_36	43° 18' 20.10837"	-123° 04' 57.25479"	203.58	227.078
OLC_UMP_37	43° 16' 32.28925"	-122° 39' 09.74917"	1035.018	1058.035
OLC_UMP_38	43° 17' 34.43038"	-122° 39' 17.97258"	783.892	806.961
OLC_UMP_39_ RTK	43° 18' 16.74387"	-123° 36' 56.08157"	603.276	626.85
OLC_UMP_40	43° 16' 05.38228"	-122° 57' 33.13323"	924.243	947.708
OLC_UMP_41	43° 30' 39.88335"	-123° 18' 55.63248"	160.341	183.446
OLC_UMP_42	43° 32' 26.05256"	-123° 17' 29.83313"	108.253	131.301

LiDAR Accuracy Assessments

Table 7: Relative accuracy

Relative Accuracy Calibration Results		
Project Average	0.072 m	0.235 ft
Median Relative Accuracy	0.059 m	0.193 ft
1σ Relative Accuracy	0.084 m	0.274 ft
2σ Relative Accuracy	0.143 m	0.469 ft
Flightlines	1,489	
Sample points	n = 54,924,260,348	

Relative Accuracy

Relative vertical accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping aream. 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, reported in Table 7 are based on the comparison of 1,489 full and partial flightlines and over 54 billion sample points.

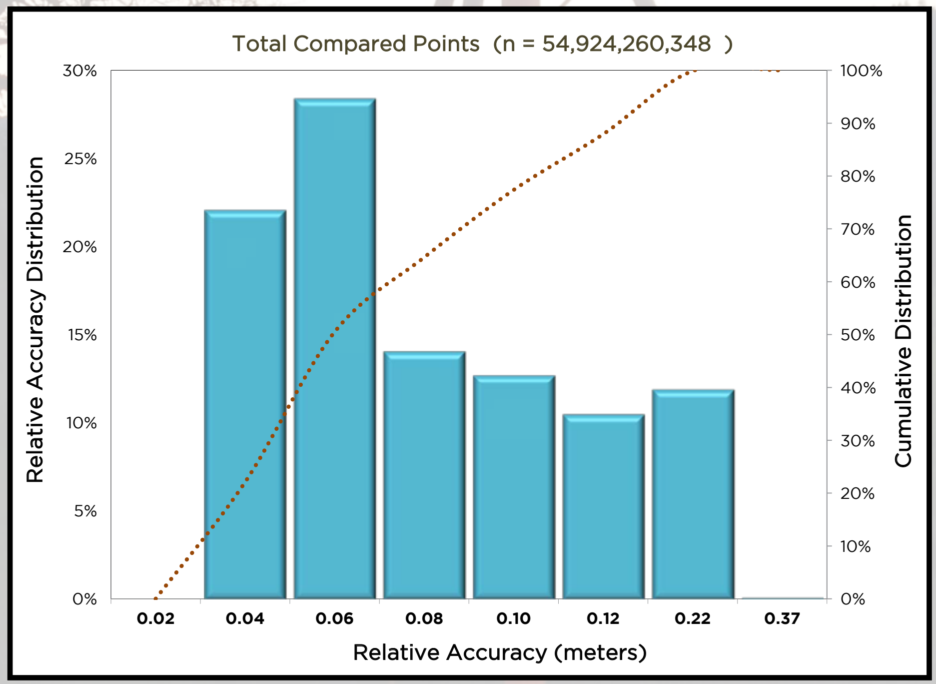


Figure 5: Relative accuracy based on 1,839 flightlines.

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 Positional Accuracy Standards for Digital Geospatial Data V1.0 (ASPRS, 2014). The statistical model compares known ground survey points (GSPs) to the ground model, triangulated from the neighboring laser points. Vertical accuracy statistical analysis uses ground survey 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 OLC Umpqua study area, a total of 24,944 GSPs were collected and used for calibration of the LiDAR data. An additional 625 reserved ground survey points were collected for independent verification, resulting in a non-vegetated vertical accuracy (NVA) of 0.062 meters, or 0.204 feet.

OLC will use quality assurance points (QAPs) acquired by OLC staff in representative, vegetated land cover to assess the vegetated vertical accuracy (VVA) of the OLC Umpqua dataset; results will be appended to this report.

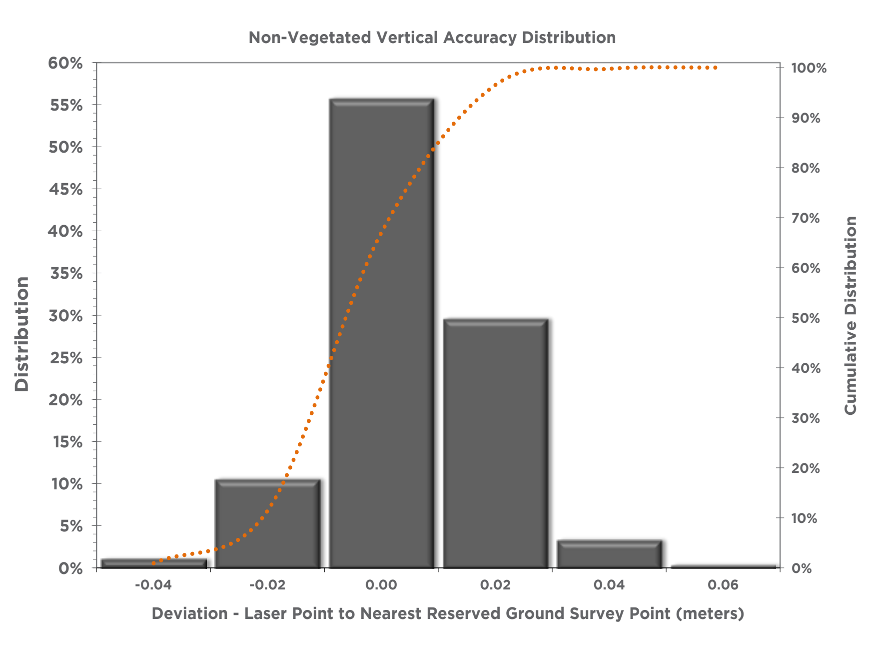


Figure 6: Vertical Accuracy distribution

Table 8: Vertical accuracy

Vertical Accuracy Results		
Sample Size (n)	625 Reserved Ground Survey Points	
NVA (RMSE*1.96)	0.062 m	0.204 ft
Root Mean Square Error	0.032 m	0.104 ft
1 Standard Deviation	0.026 m	0.085 ft
2 Standard Deviation	0.066 m	0.217 ft
Average Deviation	0.023 m	0.077 ft
Minimum Deviation	-0.176 m	-0.579 ft
Maximum Deviation	0.142 m	0.467 ft

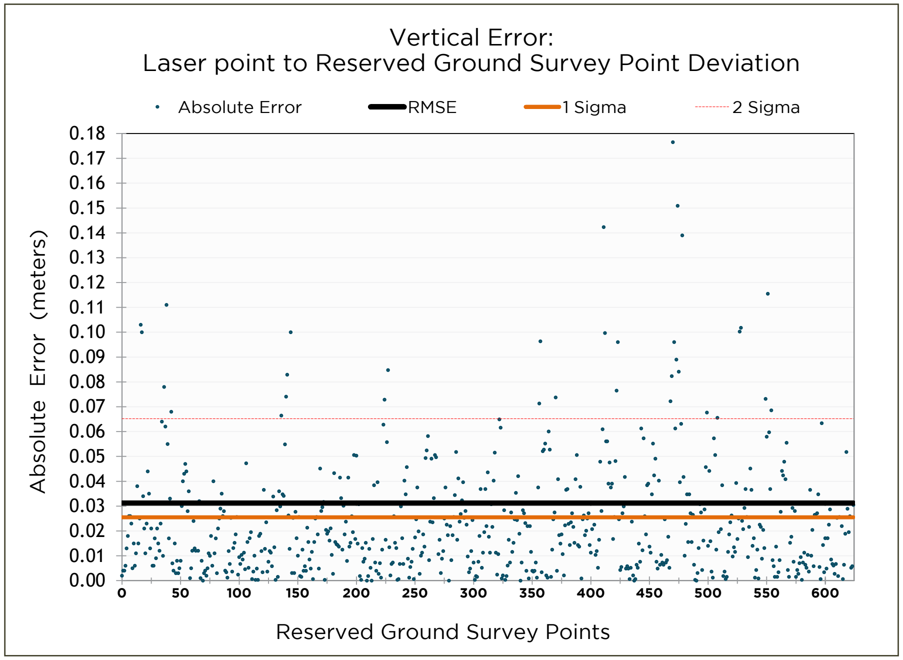


Figure 7: GSP absolute error

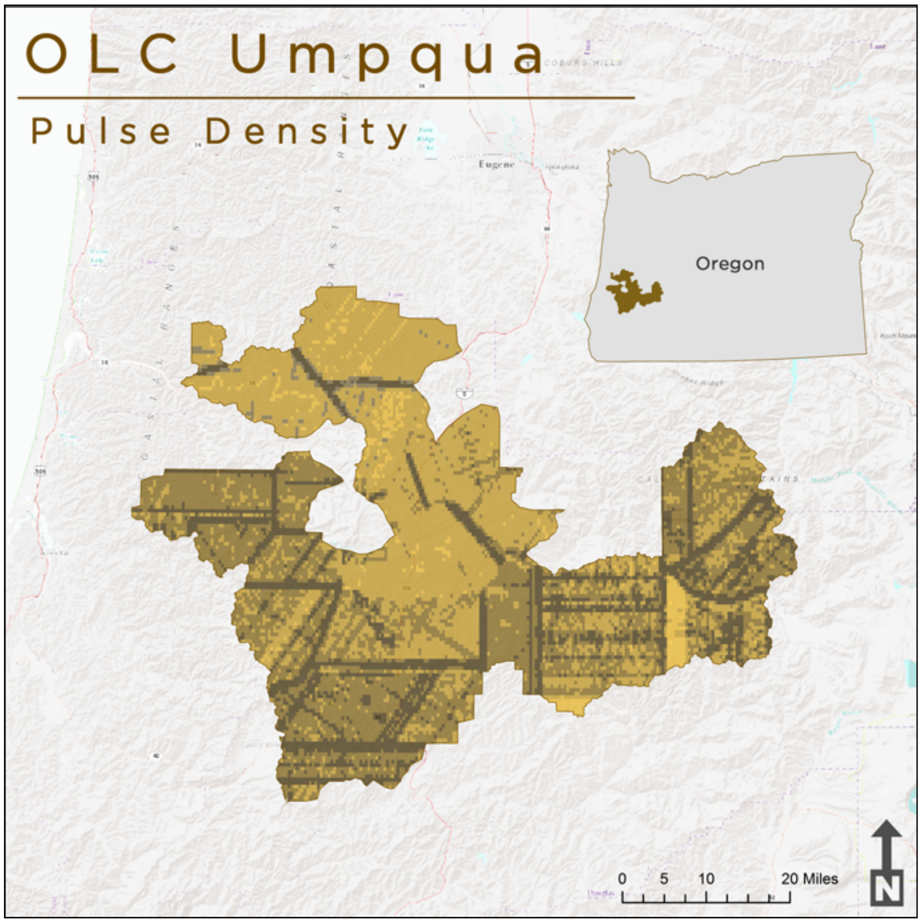
Density

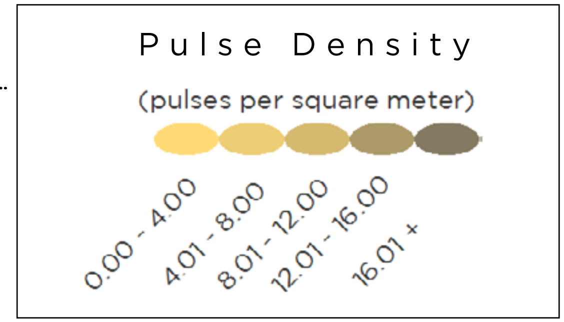
Pulse Density

Final pulse density is calculated after processing and is a measure of first returns per sampled area. 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. Densities are reported for the delivery area.

Table 9: Average pulse density

Average Pulse Density	pulses per square meter	pulses per square foot
	12.96	1.20





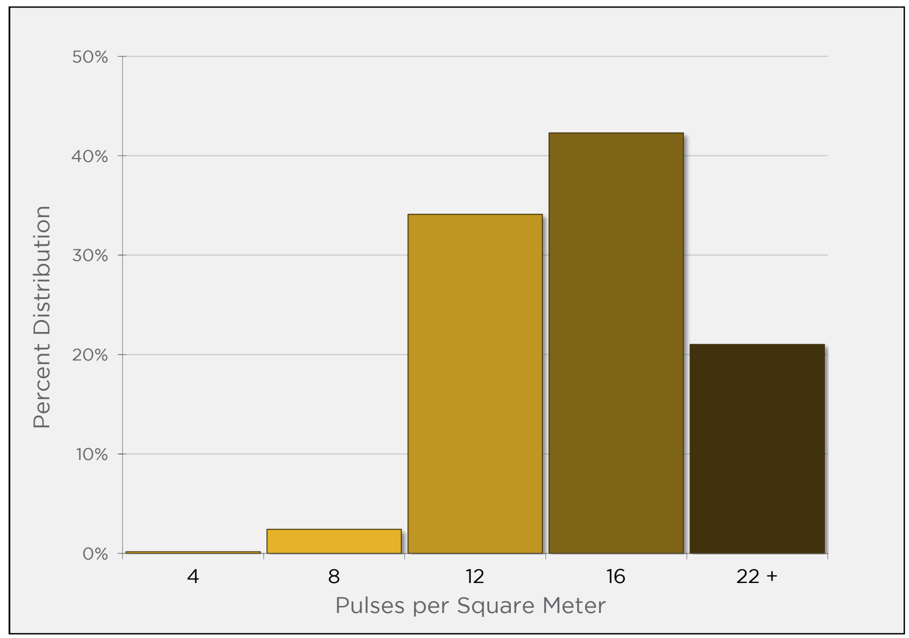


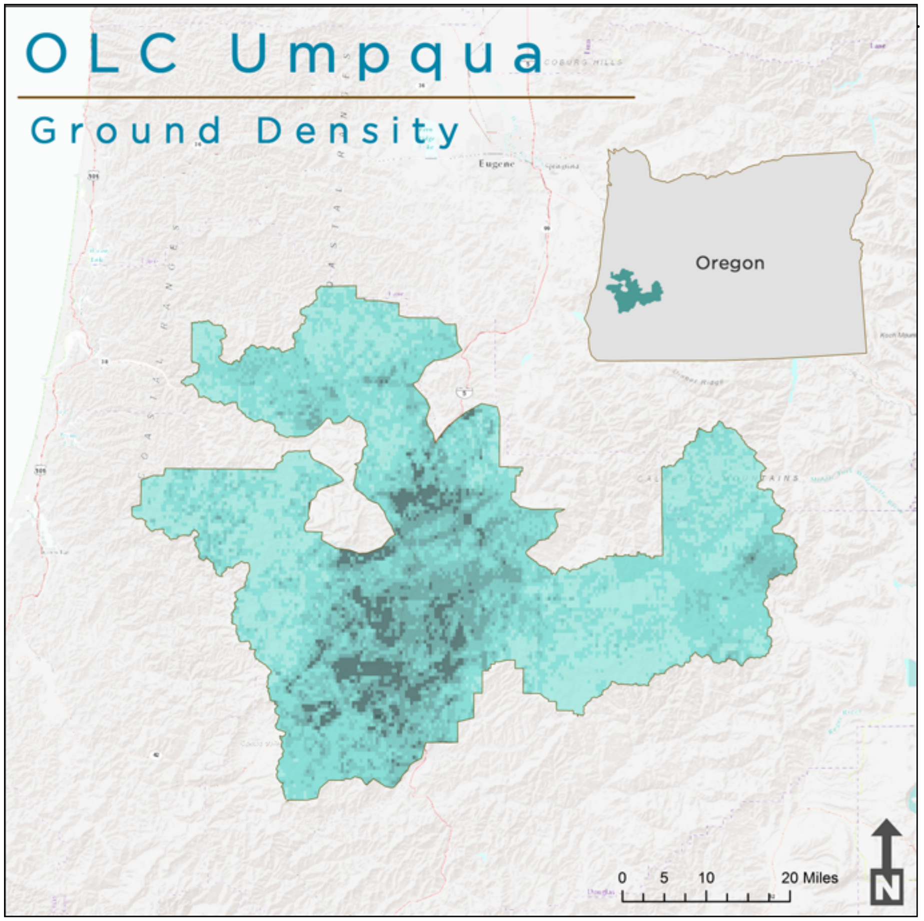
Figure 8: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).

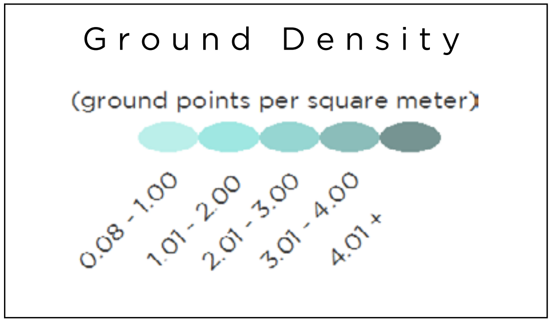
Ground Density

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. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density in Table 10 is a measure of ground-classified point data for the delivery area.

Table 10: Average ground density

	points per square meter	points per square foot
Ground Density	1.80	0.17





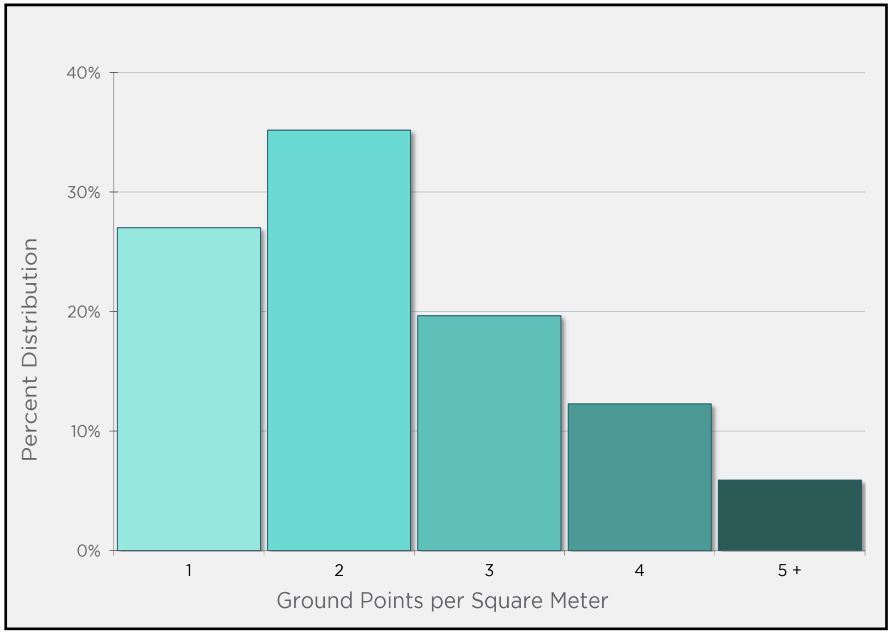


Figure 9: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).

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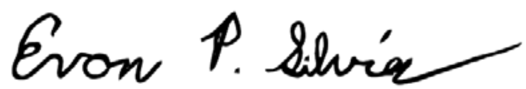
Appendix A : PLS Certification

Certifications

Quantum Spatial, Inc. provided LiDAR services for the 2015 OLC Umpqua project as described in this report.

I, Evon P. Silvia, being duly registered as a Professional Land Surveyor in and by the state of Oregon, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between February 12, 2015 and March 10, 2015 and between August 19, 2015 and October 11, 2015.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the “National Standard for Spatial Data Accuracy”.



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